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ABSTRACT

This is the third book in a sequence of four volumes written and designed for parents of students of science, particularly for those at the lower and upper elementary and junior high or intermediate level, senior high students, college students preparing to teach science, and all those individuals who are interested in science and the application of science in daily life. This volume consists of three chapters that contain 99 discrepant events (occurrences or happenings which go against what we usually think likely) dealing with Newton's Laws of force and motion as applied on earth as well as in outer space. Some aspects of geology and astronomy are also discussed. Instructions for each event include materials, procedure, questions, and an explanation. Emphasis is placed on the use of simple materials. A list of available science educational materials from Science Inquiry Enterprises is included and an index is provided. (LZ)

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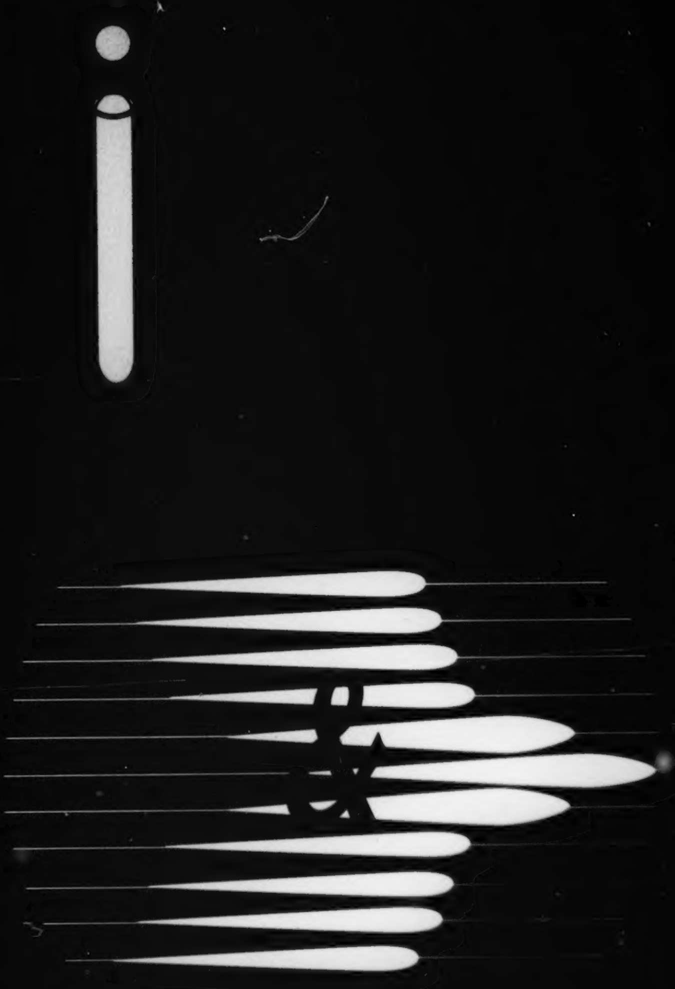

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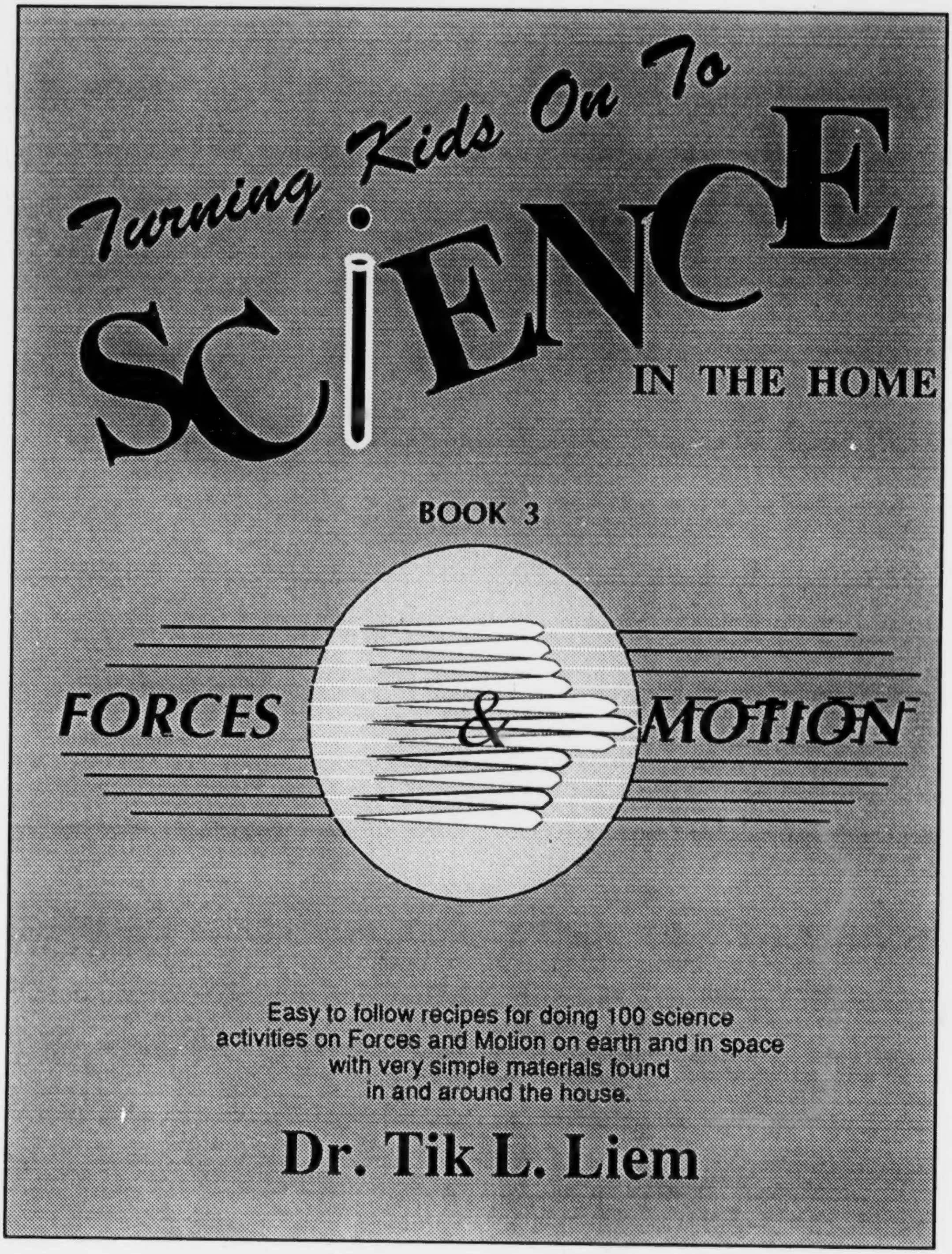

Turning Kids On To SCIENCE IN THE HOME

BOOK 3

FORCES & MOTION

Easy to follow recipes for doing 100 science
activities on Forces and Motion on earth and in space
with very simple materials found
in and around the house.

Dr. Tik L. Liem

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Book 3 - FORCES & MOTION"

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TO THOSE PARENTS
WHO WANT TO PUT MORE *Excitement*
IN THEIR CHILDREN'S LIFE

🔥 CAUTION ☠

- Only with adult supervision may children use this book!

- Fire may only be used with adult supervision!
  All fire hazardous events are marked with this symbol: 🔥

- Chemicals and/or electricity may only be used under adult supervision! Never touch chemicals with your bare fingers: poisonous chemicals can even be absorbed through the skin!
  Hazardous events involving chemicals are all marked with: ☠

- The use of chemicals always brings with it some hazards. It can be dangerous, but when handled properly it can be lots of fun!

- When working with a flame or when a flame is involved in an event, always have a carbondioxide or Halon fire extinguisher at hand.

- Always follow instructions - the "How to do it" - very carefully!

- Never work all by yourself. Always have someone with you ready to turn the fire or electricity off, if something goes wrong.

- **The author of "Turning Kids On To Science In The Home" is not responsible for any accidents resulting from irresponsible or incompetent use of the demonstrations and activities suggested in this book.**

- Although some events are rather dangerous, but if the instructions are carefully followed, they can give you a lot of joyful moments!

So, have lots of fun!

CONTENTS BOOK 3

INTRODUCTION TO BOOK 3 i

INSTRUCTIONS FOR PARENTS iii

1. Presentation : iii
2. Interaction: iii
3. Involvement: iii

BOOK 3 1

FORCES AND MOTION ON EARTH AND IN SPACE 1

CHAPTER 1 3

HOW DO FORCES AFFECT THINGS ? 3

GRAVITY 5

3.1.01. ROLLING UPHILL ? 5
3.1.02. WILL PAPER FALL LIKE A STONE ? 6

NEWTON'S SECOND LAW & GRAVITY 7
3.1.03. THE FALLING PENNIES 7
3.1.04. HIT THE FALLING CAN 8

CENTER OF GRAVITY 9
3.1.05. THE BALANCING PINS 9
3.1.06. THE BALANCING ACT 10
3.1.07. HANG A HAMMER ON A LOOSE RULER 11
3.1.08. THE PLATE CAROUSEL 12

TORQUES & CENTER OF GRAVITY 13
3.1.09. THE BURNING CANDLE SEESAW 13

CENTER OF GRAVITY 14
3.1.10. WHERE IS THE BALANCING POINT ? 14

CENTER OF GRAVITY & HUMAN BODY
3.1.11. ARE WOMEN STRONGER THEN MEN ? 15
3.1.12. THE UNREACHABLE CUP 16
3.1.13. STUCK TO THE WALL ? 17

CENTER OF GRAVITY & ADHESION **18**
3.1.14. THE CENTER-SEEKING PAPER 18

CENTER OF GRAVITY & SHOCK ABSORBERS
3.1.15. THE STANDING MATCHBOX 19

CENTER OF GRAVITY & AIR RESISTANCE **20**
3.1.16. STAND A DOLLAR BILL ON YOUR FINGER 20

CENTER OF GRAVITY & SPINNING OBJECTS **21**
3.1.17. THE WOBBLING CIRCLES 21
3.1.18. KICK A STRAIGHT LINE 22
3.1.19. STAND A RAW EGG ON ITS HEAD 23

TORQUES **24**
3.1.20. THE FLOATING BELT HANGER 24
3.1.21. THE FORK AND THE SPOON ACT 25
3.1.22. THE WEIGHTED PIPE 26

CENTER OF GRAVITY, FRICTION & TORQUES **27**
3.1.23. THE GOLDEN MIODDLE 27

ADHESIVE FORCES & FRICTION **28**
3.1.24. THE MAGIC STRIP OF NEWSPAPER 28

FRICTION **29**
3.1.25. THE INVISIBLE GLUE 29

WATER PRESSURE **30**
3.1.26. THE CARDBOARD BOTTOM 30
3.1.27. THE SQUIRTING WATER HOLES 31

WATER PRESSURE & VORTEX IN A LIQUID **32**
3.1.28. THE OUTPOUR RACE 32

THE PENDULUM **33**
3.1.29. HIT THE BOTTLE ON THE BACK SWING ? 33
3.1.30. HOW MANY SWINGS CAN YOU GET ? 34

LATENT FORCES **35**
3.1.31. THE MAGIC COME-BACK CAN 35

CENTER OF GRAVITY & SUDDEN STRESSES **36**
3.1.32. THE INCREDIBLE STICK 36

CONSERVATION OF MOMENTUM & ELASTICITY **37**
3.1.33. IS THE BALL REPELLED ? 37

RIGIDITY **38**
3.1.34. PIERCE A POTATO WITH A STRAW ? 38

STRENGTH OF WEAVED MATERIAL **39**
3.1.35. THE LOOSE KNIFE SUPPORTS 39

STRENGTH OF CORRUGATED MATERIAL **40**
3.1.36. THE DOLLAR BILL BRIDGE 40

STRESSES IN PAPER **41**
3.1.37. HOW LONG CAN YOU HOLD THE BURNING PAPER ? 41

STACKING FORCES **42**
3.1.38. THE STICKY KNIFE 42

NEWTON'S THIRD LAW **43**
3.1.39. HOW CAN WE GET THE CORK OUT? (I) 43

FRICTION **44**
3.1.40. HOW CAN WE GET THE CORK OUT ? (II) 44

COMPRESSION & WATER PRESSURE **45**
3.1.41. THE WATER HAMMER 45

SHEARING **46**
3.1.42. PUSH A NEEDLE THROUGH A BALLOON ? 46

STRETCHABILITY **47**
3.1.43. THE WATER-TIGHT ZIPLOCK BAG 47

FREE FALL & CENTER OF GRAVITY **48**
3.1.44. THE MYSTERIOUSLY MOVING BALL 48

PERPENDICULAR FORCES

3.1.45. CRUSH THE CAN WITH A RUBBER BAND ? 49

ROTATIONAL FORCES & TORQUES

3.1.46. THE CONFUSED TWIRLING PAPER 50

ROTATIONAL VIBRATIONS & DIRECTIONAL OSCILLATIONS **51**
3.1.47. THE YIP-YIP STICK 51

PRESSURE VS FORCE **52**
3.1.48. CRACK A NUT 52

SIMPLE MACHINES
FIRST CLASS LEVERS **53**
3.1.49. TILT A HEAVY LOAD WITH ONE FINGER 53

SECOND CLASS LEVERS **54**
3.1.50. IS THE HAMMER A LEVER ? 54

THIRD CLASS LEVERS **55**
3.1.51. THE THIRD CLASS BICEPS 55

INCLINED PLANE **56**
3.1.52. WHICH ONE IS HEAVIER ? 56

PULLEYS **57**
WHICH ONE WILL BE MOVED ? 57

CHAPTER 2 .... **59**

WHAT DO WE LEARN WHEN DEALING WITH SPACE SCIENCE ? **59**

INERTIA **61**
3.2.01. PUT THE COIN IN THE CUP 61
3.2.02. PULL THE TABLECLOTH 62
3.2.03. THE IMMOVABLE PENNY 63

NEWTON'S FIRST LAW **64**
3.2.04. ANOTHER BALANCING ACT 64
3.2.05. PULL THE DOLLAR BILL OUT ? 65

NEWTON'S FIRST LAW & INERTIA **66**
3.2.06. GET THE EGG IN THE GLASS 66

DIRECTION OF FORCE & INERTIA **67**
3.2.07. GET THE CHALK IN THE BOTTLE 67

NEWTON'S FIRST LAW & INERTIA **68**
3.2.08. BREAK THE STRING WHEREVER YOU WANT 68

NEWTON'S FIRST LAW **69**
3.2.09. WHAT BREAKS THE THREAD ? 69
3.2.10. THE APPLE AND THE KNIFE 70

NEWTON'S SECOND LAW & ACCELERATED MOTION **71**
3.2.11. THE FALLING WASHERS 71

NEWTON'S THIRD LAW **72**
3.2.12. THE BALLOON RACE 72
3.2.13. THE MATCH MISSILE 73
3.2.14. THE MILK CARTON SPRINKLER 74
3.2.15. THE STRAW ROCKET 75
3.2.16. BLOW YOUR OWN SAIL ? 76

CONSERVATION OF MOMENTUM **77**
3.2.17. THE RECOILING SKATE 77

CENTRIPETAL FORCE **78**
3.2.18. THE STICKY PENNY 78
3.2.19. THE FLYING WINE GLASSES 79
3.2.20. MEASURE THE CENTRIPETAL FORCE 80

CENTRIPETAL FORCE & GRAVITATION **81**
3.2.21. THE GRAVITY MACHINE (I) 81
3.2.22. THE GRAVITY MACHINE (II) 82

CONSERVATION OF MOMENTUM **83**
3.2.23. THE FUNNY MARBLES 83
3.2.24. THE CRASHING SKATES 84
3.2.25. THE COLLIDING STEEL BALLS 85
3.2.26. HOW HIGH WILL THE BALL BOUNCE ? 86

CONSERVATION OF MOMENTUM & RECOIL **87**
3.2.27. THE TEST TUBE CANNON 87

CENTER OF GRAVITY & ANGULAR MOMENTUM **88**
3.2.28. THE SPINNING PLANETS 88

ANGULAR MOMENTUM **89**
3.2.29. THE PAPER CARD BOOMERANG 89

ANGULAR MOMENTUM & MOMENT OF INERTIA **90**
3.2.30. THE SPINNING FOOTBALL 90

ANGULAR MOMENTUM & PRECESSION **91**
3.2.31. THE HUMAN GYROSCOPE 91

ANGULAR MOMENTUM & MOMENT OF INERTIA **92**
3.2.32. THE TIN CAN RACE 92

WEIGHTLESSNESS 93
3.2.33. THE CUP OF COFFEE DROP 93
3.2.34. THE FALLING ELEVATOR 94
3.2.35. THE WEIGHTLESS NAIL 95

CHAPTER 3 97

WHAT ARE SOME PHENOMENA OF THE EARTH AND THE MOON ? 97

EROSION & WEATHERING 99
3.3.01. MAKE STALACTITES & STALAGMITES 99
3.3.02. CAN STONES DISSOLVE ? 100
3.3.03. CAN PLANTS BREAK ROCKS ? 101
3.3.04. HOW CAN WATER BREAK ROCKS ? 102

ISOSTATICS & EROSION 103
3.3.05. WHY DO ERODED MOUNTAINS KEEP RISING ? 103

GEYSER ACTION & VOLCANIC ACTION 104
3.3.06. HOW DOES A GEYSER WORK ? 104

SPECIFIC GRAVITY 105
3.3.07. WHAT IS THE ROCK'S S.G.? 105

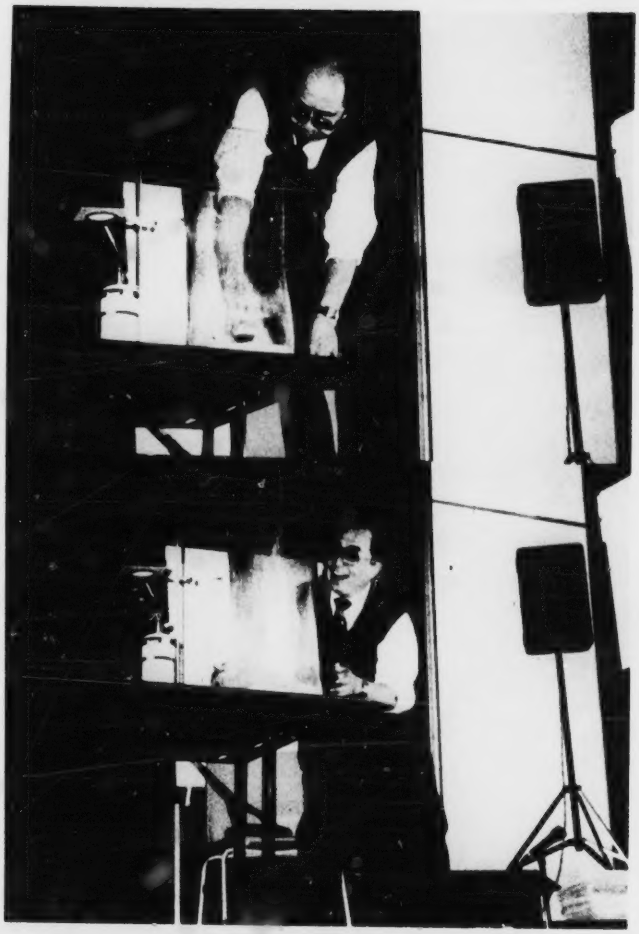
ROCKS & DENSITY 106
3.3.08. HOW CAN WE DETERMINE THE ROCK'S VOLUME? 106

VOLCANIC ERUPTION 107
3.3.09. SIMULATE A VOLCANO ERUPTION 107

ASTRONOMY 108
3.3.10. WHAT CAUSES THE PHASES OF THE MOON ? 108
3.3.11. WHAT CAUSES AN ECLIPSE ? 109

INDEX 111

DEMONSTRATION



IS TEACHING

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INTRODUCTION to BOOK 3

This book is the third book to a sequence of four volumes, written and designed for parents of students of science, particularly for those at the lower and upper elementary, and junior high or intermediate level, for senior high students, for college students preparing to teach science, and for all those individuals who are interested in science and the application of science in our daily life.

In this space age where science plays a major role in determining whether a country or even a personal life will be able to advance or progress, I feel that the understanding of science concepts and science principles will strongly help towards this goal. Statistics and test results have shown that American youngsters can't perform the simplest technical functions. A recent report of a study done by the Educational Testing Service in Princeton, New Jersey mentioned that American nine-graders were compared with same age level children of five other countries and four Canadian provinces, and they came out on the bottom in mathematics and very near the bottom in science! This is very sad news, even worse is their prediction that in the year 2000 there will be a shortage of close to a quarter million engineers, physicists, chemists, and biologists in the USA.

Where lies the problem? What makes the USA so lagging behind other countries, like: Japan, Western European countries, and in recent years some of the Pacific Rim countries? This lagging is not only economically, but especially in academic achievements of students in the field of mathematics and science! Could it lie in the way math and science is being taught in our schools? Could it lie in the way math and science is being presented to our young children? These questions come up in my mind when too many children I talked to said, that they do not like math and science in their schools. Could the problem be that school teachers do not have enough background in mathematics and science? And because of this, that they are conveying the message to students that math and science are a chore and really not fun to study? Could it be that schools do not have enough materials for doing science? Could it be that at home, our young children are also not getting any encouragement from their parents to go in the fields of science and mathematics?

I think it is a combination of all those mentioned, especially I think that not enough **enthusiasm** in science is being shown in the home as well as in the schools. If teachers as well as parents of students can show more excitement and **enthusiasm in science**, and not be afraid to actually show their enjoyment in doing science in front of the children, there is no doubt in my mind that more of our younger people will find science exciting, and continue studying in the field of science!

In the teaching of a science concept, it is most essential for the teacher to arouse the students' curiosity. Unless the student wants to know what the teacher has to say, it is most likely that time and effort in trying to teach the student would have been completely wasted. The first task of a teacher is to attract the attention of the student. This goes for all levels of learning, whether it is primary grade or college. A student without interest is the desperation of any teacher. In fact, the main objective of formal education is the arousing of the students' interest, if nothing else. Once curiosity is aroused the student will learn much more on his/her own than the teacher can ever teach him/her. Learning only takes place if the student wants to learn!

In this book the description of each of the **exciting events** is organized in such a way as to provide the user with the maximum guidance for conducting a science inquiry lesson. Emphasis has been placed on the use of simple material so that most of the events may be carried out with things that are found in everyday life or may be bought in local stores.

When you as a parent, use this book, you are actually becoming your child's or children's own private teacher! Isn't that exciting! All the statements concerning the teacher apply therefore, to you as well. The questions are there for each of the **exciting events** to be posed to the learner. The explanation is always there on each of the pages to give you the support you need in answering the questions. You can, of course, add your own questions if you want to go into more depth in each of the events.

The use of exciting events in the teaching of science is one of the best methods to arouse interest and curiosity. These **exciting events**, sometimes also called **discrepant events**, mind-capturing, or intuition-offending, are occurrences or happenings which go against what we usually think likely. Each of the events is set up in such a way that it poses a question to the student and asks him/her to come up with the explanation. There is evidence that students will remember science concepts longer when they were engaged in experiencing **exciting events**. This series of books is a collection of thoroughly tested **exciting events**. They can be used to start a lesson in almost any topic of science at the elementary or secondary level. They can also be used as reinforcement activities in the homes or as challenging problems for further inquiry. Each of the events is a focus for inquiry teaching, a most appropriate way of reflecting the true nature of science in the homes. The students are required to put into practice most of the science processes when engaged in inquiry.

The science concepts in this series of books are organized in such a way that it makes most sense:
Book 1: **Our Environment**, consisting of the chapters: Air, Flowing Air, Weather, Characteristics of Matter, and Chemicals in our Environment.
Book 2: **Energy**, consisting of the chapters: Forms of Energy, Heat, Magnetism, Static & Current Electricity, Light, and Sound.
Book 3: **Forces & Motion**, containing chapters: Forces Affecting Things, Forces and Principles in Space Science, Some Phenomena in Earth Science.
Book 4: **Living Things**, containing the chapters: Plants, and Human Biology.

In order to make it easier to find where certain topics are being dealt with, each of the books has its own **table of contents** in the front and an **index** in the back of the book. **Introductions** are placed in front of each book, so that each of the books can be used independently from each other.

INSTRUCTIONS FOR PARENTS

Please follow these instructions for the Teaching Procedure in using **Turning Kids On To Science in the Home** as close as possible, so that your lesson will be most effective:

1. **Presentation :**
   Present to the learner or involve the learner with the **exciting event** by describing or commenting on the names of objects and operations only and not mentioning the reasons for the occurrence. In other words, you may tell the student what you are doing and what materials you are handling, but not the reason why something is happening.

2. **Interaction**:
   Ask the learner questions that eventually will lead him/her to the main reason for the occurrence. In doing this, the students will be engaged in science inquiry and actually practicing the science processes of observing, measuring, inferring, predicting, interpreting data, identifying and controlling variables, hypothesizing, and experimenting.

3. **Involvement**:
   Participate the learner in similar (and simpler) **exciting events** or exciting activities, that are based on and illustrating the same science concept. This will reinforce the learning and retention of that particular concept. Students may work individually or together with you.

It is essential that the presentation of the **exciting event** or the involvement of the students in the event takes place under the following conditions. Think of giving the student: **INSIGHT!**

IN = Arouse Interest
The event should confront the student with a perplexing problem. It should be presented almost like the way a magician would do a magic act.

S I = Use Simple Materials
The event should be performed with materials that are familiar to the student, in other words use simple materials that can be found in daily life.

G = Use all Gateways
Use all the gateways into the brain, meaning students should have the opportunity to observe as well as carry out the events themselves. They should be allowed to totally experience the exciting event (by using all five senses).

H = Hinge it with Examples
When dealing with the concept underlying the event, examples and applications of the concept in our daily life should be mentioned to make it more meaningful to the student.

T = Tie it all together with Joy and Enthusiasm
Show genuine enthusiasm in presenting the puzzling event and don't be afraid to show your own enjoyment in the subject matter in general!

ENJOY YOURSELVES !

BOOK 3

FORCES AND MOTION ON EARTH AND IN SPACE

This book consists of three chapters dealing with **Newton's Laws of force and motion**, applied on earth as well as in outer space. Some aspects of **geology** and **astronomy** are also discussed.

Chapter 1 deals specifically with the concept of:
- gravity and the center of gravity of objects and systems,
- how torques can keep objects in balance,
- latent forces in rubber bands,
- the effect of sudden forces,
- simple machines,
- and the rate of falling objects.

Chapter 2 concentrates more on concepts and laws that can be applied to space science, Like:
- inertia,
- Newton's First, Second, and Third Laws;
- centripetal and centrifugal forces;
- conservation of momentum and plane of rotation;
- and weightlessness.

Chapter 3 deals with some aspects of geology and a few phenomena in astronomy:
- erosion and weathering,
- volcanic action,
- and eclipses.

Create in the student

an *Eager Want*

THE BALANCING PINS

Why does the system of pins, ball, and stoppers not tip over ?

CHAPTER 1

HOW DO FORCES AFFECT THINGS ?

After dealing with and studying the concepts and sub-concepts of this chapter, the students should be able to:

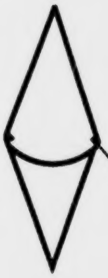
a. recognize the correct explanation of an observed event based on each of the sub-concepts;
b. explain in their own words which of the sub-concepts is determining the course of an event;
c. distinguish true from false statements concerning each one of the sub-concepts;
d. Identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

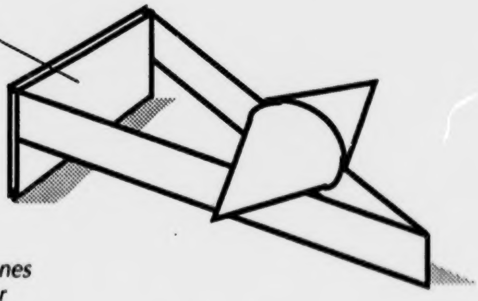
— Gravity pulls objects toward the center of the earth.
— Falling objects fall at the same rate (in a vacuum).
— If the center of gravity of a system is located below its point of support (pivot point), it is a stable system.
— Spinning objects spin around their center of gravity.
— A torque consists of two forces working in opposite directions, which cause an object to spin or rotate.
— Water pressure increases with the depth of the water.
— The frequency of a pendulum swing depends only on the length of the pendulum: the shorter the pendulum, the higher the frequency.
— Corrugations, filling with compressed air, or weaving will generally strengthen the material.
— In a first class lever the fulcrum is between effort and resistance.
— In a second class lever, resistance is between fulcrum and effort.
— In a third class lever, effort is between fulcrum and resistance.
— Inclined planes and pulleys, like first and second class levers, are meant to reduce the effort to lift or move heavy objects.

3.1.01. ROLLING UPHILL ?

What you need: 1. Strips of cardboard (about 3 cm wide). 2. Paper cards and cellotape.



Sketch A



Sketch B

How to do it:

1. Make a cardboard ramp in the shape of a narrow V, and tape a wider cardboard strip to the open end of the V, so that this end will be about 2 cm higher (see Sketch B).
2. Construct two identical cones from the paper cards and tape them together (see Sketch A). Make sure that the surface of the double cone is smooth (especially where it is taped).
3. Place the double cone on the lower end of the V-shaped ramp and give it a starting push toward the higher end.

What to ask:

1. How can an object roll uphill?
2. Does the double cone actually end up higher above the table top?
3. Would a cylinder roll up the V-shaped ramp?
4. What force made the double cone roll toward the open end of the V?
5. What would a sphere do on the V-shaped ramp?

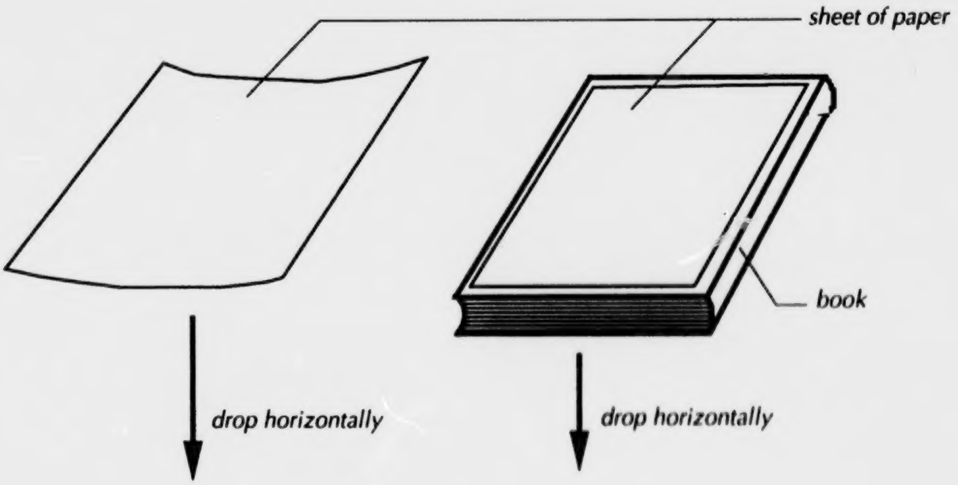
How to explain it:

This demonstration invites students to be very observant. It gives the **illusion** of the double cone rolling uphill. The fact is that the double cone actually rolls downhill. It started higher above the table top at the lower end of the V-shaped ramp and ends up lower above the table top at the higher end of the ramp. It can be observed by fixing the eye on the tip of the double cone or actually **measuring** the distance between this point and the table top before and after the rolling.

It is because of the shape of the double cone and that of the ramp, that the object's **center of gravity** slightly gets lowered when rolling from the tip to the open end of the V-shaped ramp. A cylindrical shaped object would not be able to roll "uphill" on this ramp. A spherical shaped object, like a ball for instance, would be able to roll towards the higher end of the ramp, but drops down much sooner between the legs of the V-shaped ramp.

3.1.02. WILL PAPER FALL LIKE A STONE ?

What you need: 1. A hard cover book. 2. A sheet of paper (the size of the book).



How to do it:

1. Drop a sheet of paper to the floor from arm's height (it will slowly fall, moving from side to side).
2. Drop a book separately (or beside the paper) to the floor from the same height (it will drop like a stone and hit the floor much sooner than the paper).
3. Now place the paper sheet on the book. Ask the students: 'With the same gravity working on the paper and the book, will the sheet of paper fall at the same rate as the book?" (Anticipated answer: 'No').
4. Drop the book with the paper sheet on top of it (make sure that the paper's size is equal to or smaller than the book).

What to ask:

1. Together why did the sheet of paper drop just as fast as the book?
2. Separately why did the sheet of paper drop slower than the book?
3. What would happen if the book were smaller than the sheet of paper and the two were dropped together?
4. What would happen if the sheet of paper were dropped in a vacuum tube?

How to explain it:

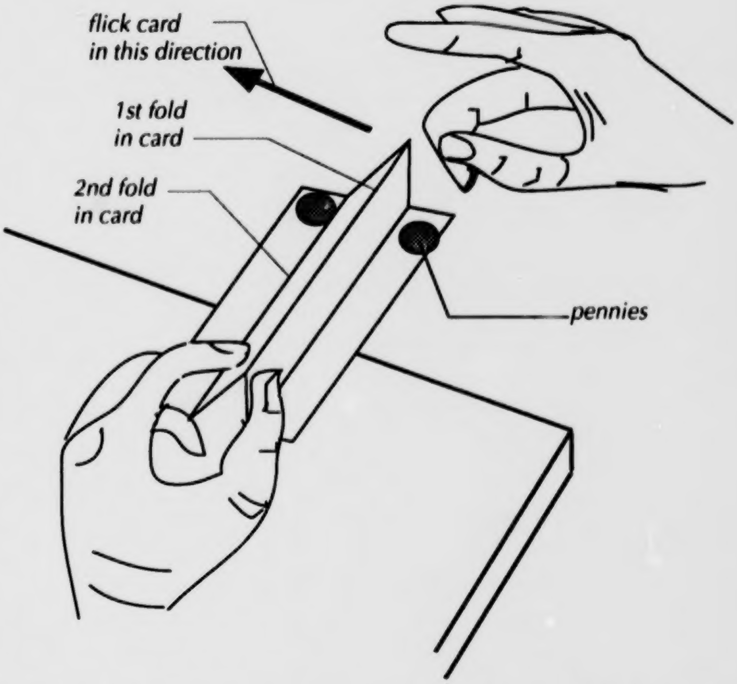
Dropping the sheet of paper to the floor by itself will make it move from side to side and descend slowly, because of the air resistance. The book is heavy enough to overcome the air friction and it drops in that short distance as if there were no resistance. Together, our intuition says that the paper should stay behind the book in falling to the floor, but they fall at the same rate, because under the paper there is no air and thus no resistance. It is as if the paper fell in a vacuum and thus it hits the floor exactly at the same time as the book does (neglecting the thickness of the book itself).

3.1.03. THE FALLING PENNIES

What you need: 1. Two pennies (or other coins). 2. A paper card (3x5" / 7x12 cm).

How to do it:

1. Fold the paper card in half, then fold each side one-third from the end outward.
2. Place the pennies on each side of the center ridge of the card and hold one end on the table edge (see Sketch).
3. Now flick the ridge of the card to the side with the middle finger of your right hand. This will fling one penny about 5 m away and at the exact same moment the other penny will drop straight down to the floor.
4. Ask the students: "Which of the two falling pennies will hit the floor first?" (Anticipated answer: 'the straight falling one'). Flick the card and listen to the click of the pennies hitting the floor.



What to ask:

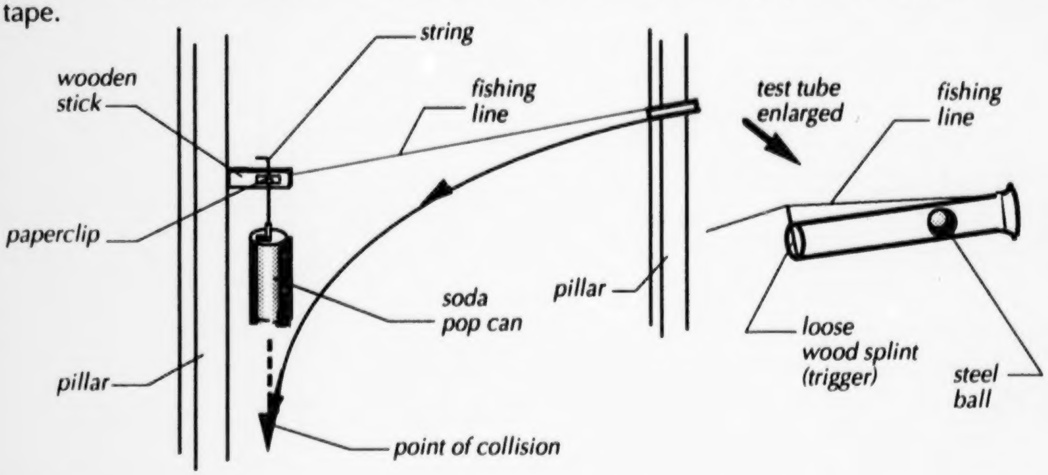
1. Did you hear one or two loud clicks of the falling pennies?
2. What would it mean if you heard only one click?
3. Does the direction of a falling object have any influence on the speed or rate of fall?
4. What was disregarded in this demonstration?
5. What can we conclude from this demonstration about the rate of fall of objects with different initial directions?

How to explain it:

As both pennies were released at the same moment, the **force of gravity** started to work on the pennies at the same time. The downward component of the forces working on each of the pennies is therefore the same, and thus also the **acceleration** they obtain, resulting in reaching the floor in exactly the same time. This is why only one loud click (first click) is heard of the two pennies falling, regardless of the initial horizontal force imparted on one of them. When one of the pennies is replaced with a marble, the same one click will result, implying that all objects fall with the same rate (in a vacuum). In our case the air resistance was disregarded, because of the relatively short distance of fall.

3.1.04. HIT THE FALLING CAN

What you need: 1. An empty soda pop can. 2. A test tube and steel ball (which fits in the tube). 3. Fishing line (6-7 m long) & short piece of string. 4. Two strong, rigid, heavy stands (two pillars about 4-5 m away from each other is ideal). 5. A wooden stick, paper clip, splint, masking tape.



How to do it:

1. Break the bottom of the test tube by letting the steel ball roll down in it (a wide glass tubing could be used here instead).
2. Tape this tube horizontally about mouth-height to one of the pillars.
3. Punch a nail hole through the end of a 20 cm long wooden stick and get the fishing line though the hole.
4. Tie a paper clip to the end of the fishing line.
5. Tape the stick, slightly higher than the tube, to the other pillar.
6. Pull the fishing line rather tight from one pillar to the other (to where the tube is taped; the line should be slightly higher at the wooden stick end).
7. Tie a short string to the empty can and pinch the end of the string between the paper clip and the wooden stick. Set the trigger by placing a wood splint at the end of the tube (can should be held up when set, when wood splint falls the can should fall).
8. Place the steel ball in the tube and blow it hard in the direction of the hanging soda can (tube and can should be lined up). - see Sketch above.

What to ask:

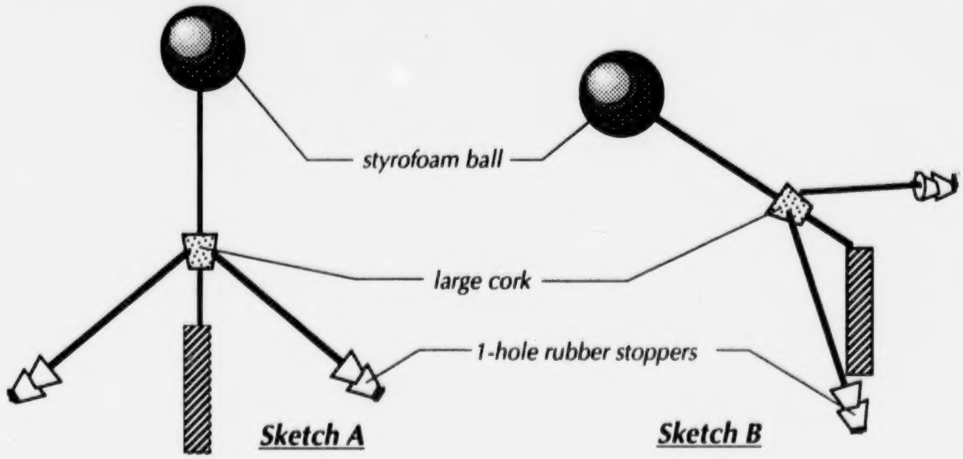
1. Why does the steel ball always hit the falling can?
2. Does it matter how hard we blow through the tube?
3. What force is pulling at all falling objects?

How to explain it:

Disregarding the **air friction** in this case (actually in **vacuum), gravity** is pulling at the can and at the steel ball with the same force, thus no matter whether the ball had a horizontal component or not, they fall at the same rate and should meet each other in their path of fall.

3.1.05. THE BALANCING PINS

What you need: 1. Three knitting needles, or iron wires (30 cm).
2. Four one-hole rubber stoppers. 3. A cork (medium size), a styrofoam ball or cube.



How to do it:

1. Stick one of the knitting needles, lengthwise, through the center of the cork, cut the head of the pin off, and stick the styrofoam ball to this end of the needle.
2. Let two of the stoppers fall in each of the remaining knitting needles through their holes.
3. Stick these pins rather slanted down into the side of the cork (Sketch A).
4. Let the whole system balance on your finger with the pin point as the pivot (use any protruding point as support).

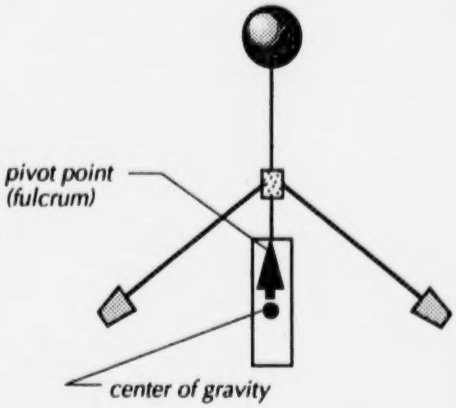
What to ask:

1. Why does the system of pins and stoppers stay up?
2. What is the purpose of the rubber stoppers?
3. What is the purpose of the styrofoam ball?
4. Where is the center of gravity of the system located? Without the pins with rubber stoppers? With the pins and rubber stoppers?

How to explain it:

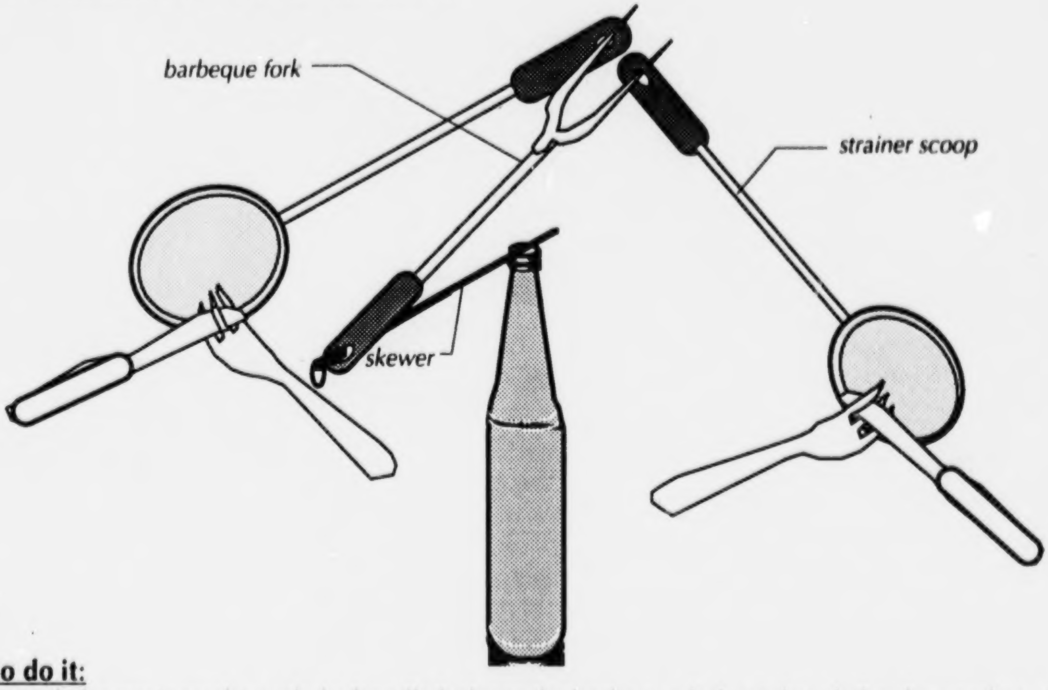
The cork and styrofoam ball are very light in weight, compared to the rubber stoppers. By slanting the pins with the rubber stoppers down, the **center of gravity** is lowered below the **pivot point.** Another way of lowering this center of gravity of the system is to shift the cork down. The lower the center of gravity of the system, the more stable the system is.

It is because of this principle that race cars are built as low as possible, so that in sharp turns they will hug the road and not roll over.



3.1.06. THE BALANCING ACT

What you need: 1. A tall pop or wine bottle. 2. Two strainer scoops, 2 forks, 2 knives. 3. A barbecue fork and a metal skewer.



How to do it:

1. Attach the strainers through the handle holes to the barbecue fork, and push the skewer through the handle hole of the barbecue fork (see Sketch above).
2. While holding the system of utensils by the end of the barbecue fork, hang more weight on the strainers by pushing the fork teeth through the strainer holes and the knives through the fork teeth.
3. Balance the whole system of utensils now on top of the coke bottle by the end of the skewer.

What to ask:

1. What makes the system stay balanced?
2. What is the purpose of the forks and knives?
3. Why doesn't the system stay balanced without the forks and knives?
4. What property is critical in deciding whether an object stays stable or unstable on a pivot point?
5. Where can we find applications of this principle?

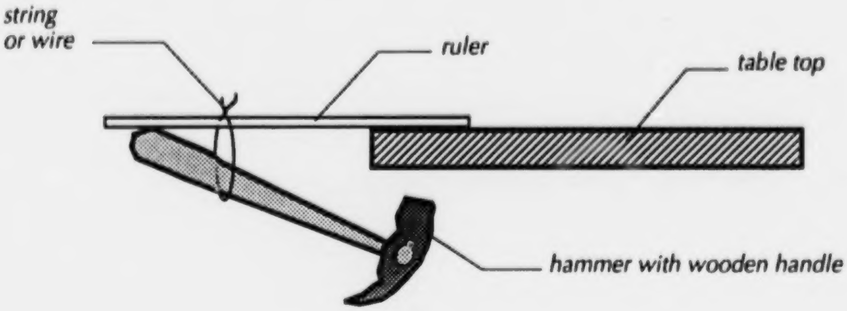
How to explain it:

The purpose of hanging the forks and knives on the strainers is to lower the **center of gravity** of the whole system, so that the system can stay stable on top of the pop bottle (pivot point). When the **center of mass** or **center of gravity** of a system is situated below the pivot point, the system is stable. **The lower the center of gravity of the system, the more stable the system is.**

An application of this principle is found with rope dancers. When they walk the ropes they carry long heavy bent poles (probably weighted at the ends) in order to stabilize themselves.

3.1.07. HANG A HAMMER ON A LOOSE RULER

What you need: 1. A hammer with a wooden handle.
2. A wooden or plastic ruler. 3. A short string or wire.



How to do it:

1. Take a flat wooden or plastic stick (the length of a ruler) and hang the hammer (with a wooden handle), with the iron part of it down, by means of a string (See Sketch).
2. Make a loop out of the string or wire (about 10 cm diameter), and slip it around the ruler and the handle of the hammer (let the end of the handle press against the ruler end).
3. Let the other end of the ruler hang from the edge of a table top.

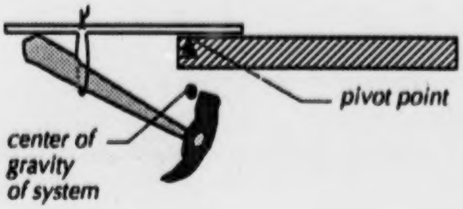
What to ask:

1. What made the heavy hammer stay up at the edge of the table?
2. Why do we need a hammer with a wooden handle?
3. Can we consider the ruler really to be loose?
4. Where is the center of gravity of the hammer alone?
5. Where is the center of gravity of the whole system of ruler, string, and hammer?
6. What is the difference between a stable and labile system?

How to explain it:

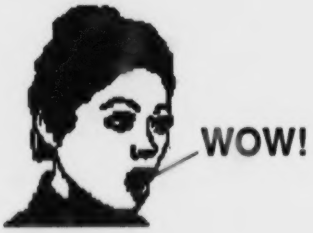
This demonstration can only be carried out when the hammer has a wooden handle, as the **center of gravity** is located in the iron part of the hammer. The plastic or wooden ruler and string do not add much to the weight of the system on the handle side. They make the position of the center of gravity of the whole system shift just a little towards the right and upwards.

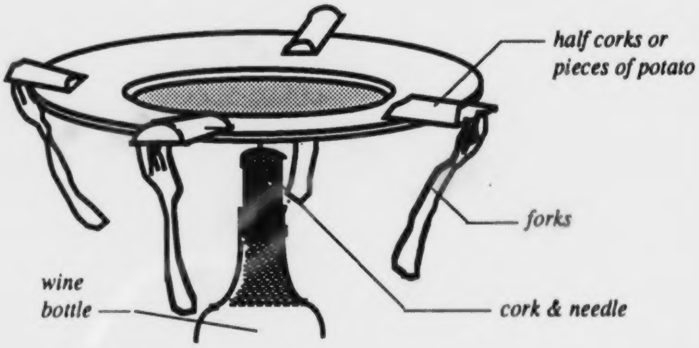
If this center of gravity is under the **pivot point (point of support),** it is a **stable system.** If the center of gravity is above the pivot point, it is **labile** and it falls.



3.1.08. THE PLATE CAROUSEL

What you need: 1. A regular dining plate and 4 forks. 2. Two corks or a small raw potato.
3. A corked bottle and a needle.





How to set it up:

1. Insert the needle vertically in the cork of the bottle and place the bottle in the middle of the table.
2. Cut the two corks in half with a sharp knife (so that the cut surfaces are smooth) or, when corks are not available, cut four equal pieces of potato out of a small raw potato.
3. Stick the four forks in the four half corks (or four chunks of potato) and hang them from the edge of the plate (see Sketch).
4. Balance the whole system of plate and forks on the blunt end of the needle (or the sharp end if you can push the blunt end in the cork).
5. Now gently blow against the forks (or tap against them) in one direction to make the plate rotate.

What questions to ask:

1. Could the plate balance on the needle without the forks?
2. What is the function of the hanging forks?
3. What did the forks do to the centre of gravity of the system?
4. Where is the centre of gravity of the plate located without the forks?
5. Where is the centre of gravity of the system of plate and forks located?
6. Would half corks or pieces of potato be better to make the system more stable, or does it matter at all?
7. Would smaller or larger pieces of potato be better to make a more stable system? Why?

How to explain it:

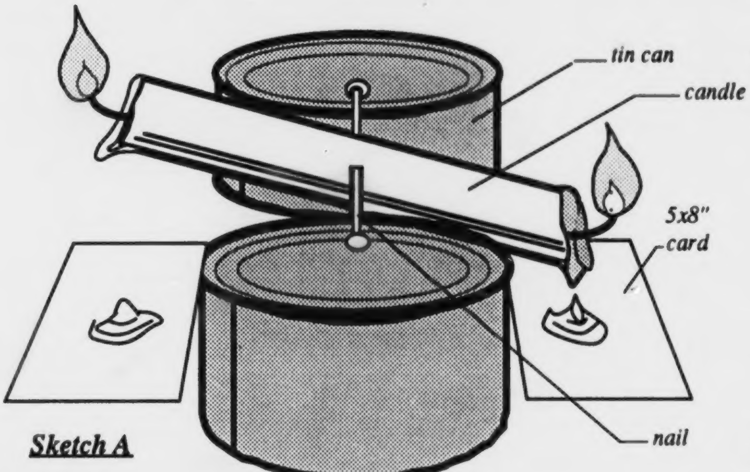
The plate on its own would not be able to balance on the needle, because its **center of gravity** would be located above the point of support (pivot point). By hanging the forks from the edge of the plate, the center of gravity of the system got lowered. It got lowered far enough below the **pivot point** that the system became stable. The more mass is placed below the pivot point, the stabler tne system. Thus, when comparing the half corks with the pieces of potato, the first would be better, as the corks are much lighter in weight (less mass). The bigger the pieces of potato we use, the less stable the system, as more mass is placed above the pivot point - which is the top of the needle.

FORCES

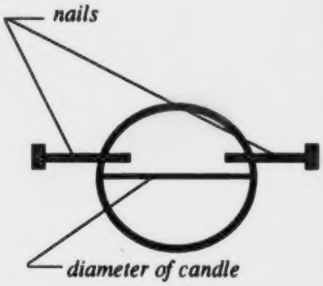
TORQUES
CENTER OF GRAVITY

3.1.09. THE BURNING CANDLE SEESAW

What you need: 1. A long, cylindrical candle & matches. 2. Two identical tin cans.
3. Two narrow, long nails or pins 4. Two 5x8" cards.



Sketch A



Cross-section of Candle Center

Sketch B

How to set it up:

1. Carve away some of the wax from the bottom end of the candle and let the wick stick out.
2. Let the candle balance on your finger to find the center of gravity. Once this point is found, make a small scratch in the candle and push the two nails in each side of the candle, such that they are lining up in each others extension, slightly above the diameter of the candle (Sketch B).
3. Place the two cans next to each other with a space in between, equal to slightly more than the thickness of the candle.
4. Rest the nails (which are already in the candle) on the rims of the cans to make the seesaw.
5. Make sure that the candle balances to a horizontal position by scraping wax off the heavier end if needed, then place the 5x8" cards under each end of the candle.
6. Light both ends of the candle and start the seesaw by pushing one end of the candle down.

What questions to ask:

1. What is the function of the nails?
2. Why do we have to make sure that the candle is in perfect balance before lighting it?
3. What keeps the candle rocking back and forth? - What keeps the seesaw going?
4. What will happen if we don't push one side down to start the rocking?
5. What will happen if - after balancing the candle on the nails - we only light one end?
6. Could we start the seesaw without scraping the wax of the heavy end of the candle? How?
7. How long will the seesawing continue? Or will it?
8. Why do the nails have to be placed slightly higher than the diameter of the candle?
9. How does this candle seesaw differ from a real seesaw with people on it?
10. Where are the forces working and what kind of forces are working on the seesaw?

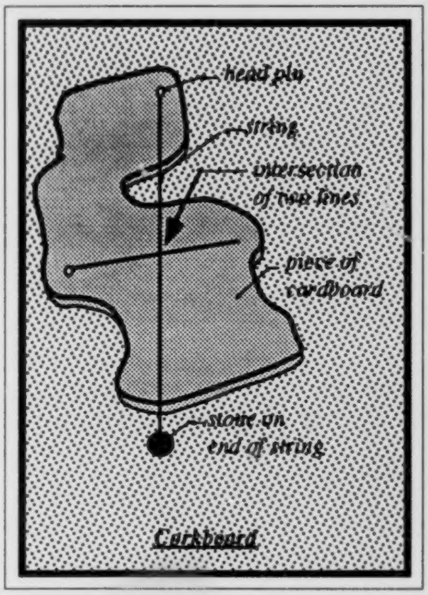
How to explain it:

The function of the nails is to work as the **pivot** of the seesaw. This has to be placed slightly higher than the diameter, so that the candle's **center of gravity** stays below the pivot point. If this center of gravity is too high, there is a danger that the candle will make a complete turn and flip over. This candle seesaw works, because it keeps on loosing one drop of candle wax weight at each end and its doing it alternatively. When one end looses one drop, the other end becomes heavier and thus goes down because of a **torque** or **moment** working on this end. The difference with the real seesaw with people, is that no weightloss is occurring in the latter, only a slight upward force with the legs on each end of the seesaw makes it go.

3.1.10. WHERE IS THE BALANCING POINT ?

What you need: 1. Pieces of cardboard. 2. A pair of scissors, and a nail..
3. A few head pins or tag pins. 4. A thin string or thread.
5. A stone or weight. 6. Pencil and foot ruler, and corkboard.

How to set it up:

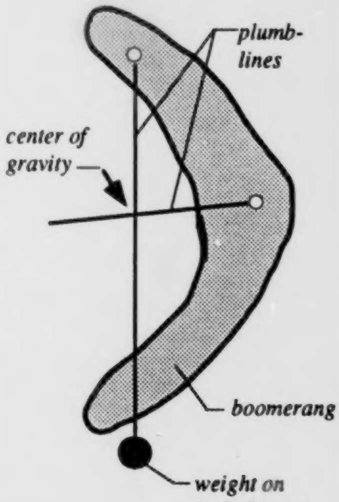


1. Cut an irregular shape out of the cardboard piece (like in the sketch above).
2. Make a hole at one end of the cardboard piece with a nail and let the cardboard hang freely from a pin which is pushed in the corkboard.
3. Now tie a string or thin thread to the pin and on the other end of the string tie a stone for weight (plumb-bob) and let it hang freely from the pin.
4. Place the ruler next to the string and draw a pencil line on the cardboard.
5. Take the pin out of the corkboard and turn the cardboard piece about 90 degrees or more and repeat points 2, 3, and 4.
6. The intersection of the two lines on the cardboard piece is the center of gravity. Show that it can actually balance on the tip of your finger, if placed exactly at this intersection.

What questions to ask:

1. Why does the cardboard have to hang freely from the pin?
2. Why do we make a hole in the cardboard with a nail first before hanging it from the pin?
3. Would a third line be necessary to determine the balancing point?
4. Where would a third or fourth line definitely go through?
5. How can we define the center of gravity? Or balancing point?
6. Is this point always on the object itself? Or can it be outside the object?
7. How would the object look like, if its center of gravity is located outside itself?

How to explain it:



The definition of **center of gravity** of an object is **a point in which you can think all the mass is concentrated.** This is why the center of gravity is definitely on the plumb-line that hangs from any point of the object. In order to find it, all we need is two of these plumb-lines, and the intersection of these two lines will therefore be the **center of gravity**, because only this point is common to the two lines. A third or fourth plumb-line is therefore not necessary, because these lines will also go through the center of gravity.

This **center of gravity** is sometimes also called **the bal-ancing point ,** because when we support the object at that point, for example with our finger tip, it will balance. It is not necessary that this point is located on the object itself. It is entirely possible that this point is outside the object. An example wouldbe that of a boomerang (see Sketch on right).

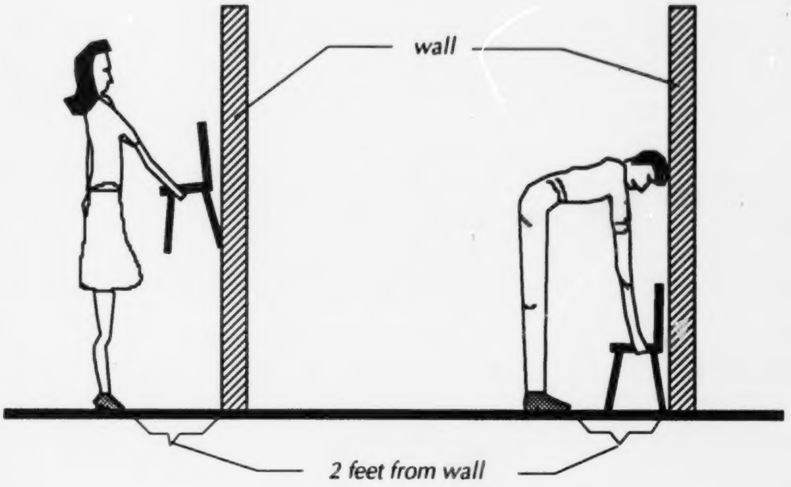
We would not be able to draw the center of gravity on the object in this case. Can you think of other objects, where this balance point is outside itself?

3.1.11. ARE WOMEN STRONGER THAN MEN ?

What you need: 1. A straight-back chair, some wall space.
2. A few adult men and women (or teenage boys and girls).

How to do it:

1. Show what the people have to do:
   a. Stand exactly two foot-lengths away from the wall (by measuring toe to heel off the wall with shoes on).
   b. Bend over with a straight back (turning in the hips) and let your head lean against the wall (see Sketch).
   c. Ask someone to hand you the straight-back chair (with the back against the wall).
   d. Lift the chair while your head is still leaning against the wall.
   e. With the chair in lifted position, try to straighten up (men cannot do this, but women can!)
2. Ask women and men to do the above alternately (hand them the chair after they have stepped back from the wall).



What to ask:

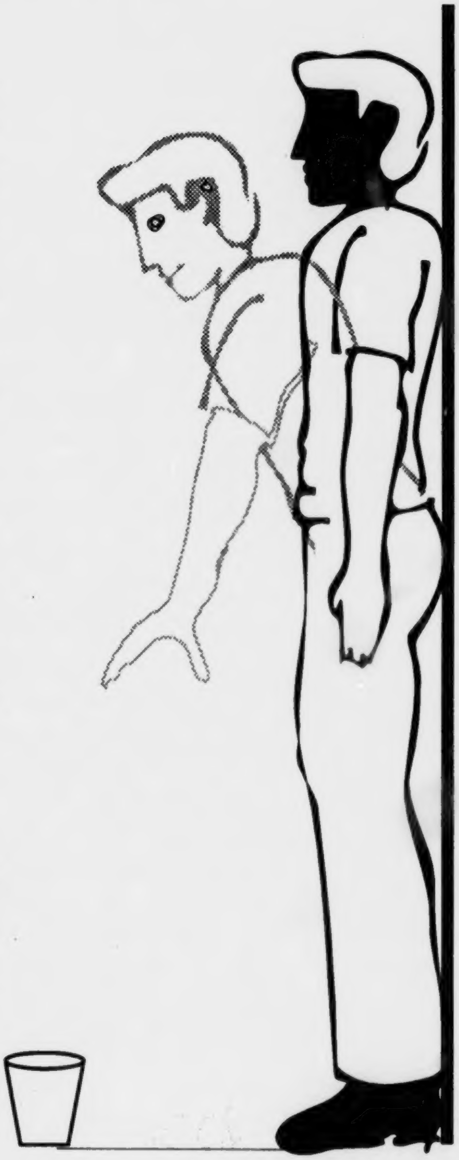
1. Why can girls or women straighten up and boys or men not?
2. Is the 'weaker' sex really stronger?
3. What is the difference in body build of male versus female?
4. Where is the center of gravity of the body located?
5. What is the average shoe or foot size of females versus males?

How to explain it:

The result of this event has nothing to do with strength. It lies in the difference of the **location of the center of gravity** of the female compared to the male body, and the difference in foot size. The center of gravity of the female body is in the hip, while that of the male body is situated higher than the hip, because of the broader shoulders and narrower hips. The male foot size is generally larger than the female one, so he stands actually farther away from the wall than she does. When he bends over his center of gravity get shifted beyond his toes, but with the female person this center of gravity stays above the foot (as pivot point), and straightening up, poses no problem.

3.1.12. THE UNREACHABLE CUP

What you need: 1. A cup or pop can (or any other small object).



How to set it up:

1. Place a cup or pop can about 20-30 cm in front of your feet on the floor and show how easy it is to pick it up without moving or bending your knees.
2. Let someone (student) stand straight with his/her back against the wall and with his/her heels touching the wall.
3. Place a cup or pop can about 20-30 cm away in front of the student's feet on the floor.
4. Let the student pick up the cup from the floor without bending the knees and without falling forwards. Is it possible?

What questions to ask:

1. What makes it so difficult to pick up the cup from the floor?
2. Why do we tend to fall forward when bending our body to the front?
3. Let the student stand away from the wall and let him/her pick up the cup from the floor without bending the knees. Observe the student from the side. What happens to the legs and lower part of the body?

How to explain it:

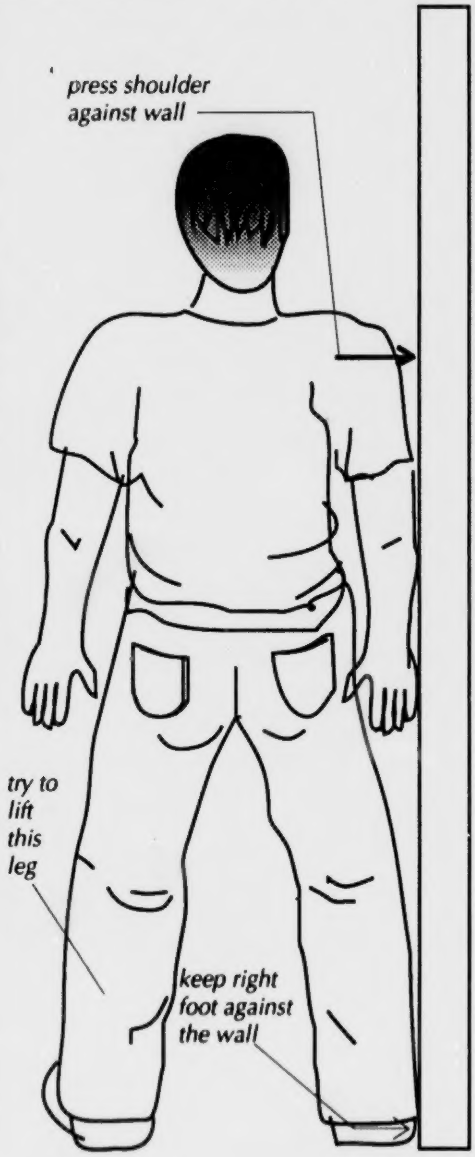
When picking up an object from the floor without bending our knees, our legs and lower part of our body have to move backwards in order to stay balanced. The **center of gravity** of our body has to remain above our feet, which is the **pivot point,** supporting our body.

Standing straight with our back against a wall makes it impossible to move the lower part of our body backwards. The forward bending of the upper body shifts the body's center of gravity towards the front of the pivot point (our feet) and the whole body topples or falls forward.

If there is no wall or one that is not too easily accessible, like in an auditorium or the outdoors, you can let two students stand back to back and heel to heel, and let them pick up the cup from the floor in front of each one of them at exactly the same time (on the count of three).

3.1.13. STUCK TO THE WALL ?

What you need: 1. Just yourself and the wall.


press shoulder against wall
try to lift this leg
keep right foot against the wall

How to set it up:

1. Stand up straight with your right foot and your right shoulder aqainst the wall.
2. Try to move your left leg without falling or taking a step.
3. Now turn around, stand straight and touch the wall with your left foot and keep your left shoulder pressed against the wall.
4. Try to lift or move your right leg: IMPOSSIBLE!

What questions to ask:

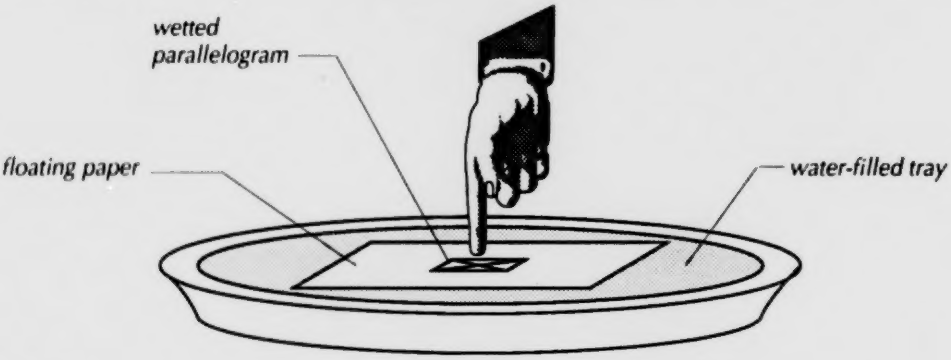
1. What makes it impossible to move your left leg when your right foot and right shoulder are touching the wall?
2. What did you have to do in order for your right shoulder to press against the wall?
3. What would happen if someone else forced your left leg to move while you are standing in that position?
4. Where is your center of gravity located when you are standing up straight?
5. Where does your center of gravity have to be located in order for you to be able to lift your left leg without falling?

How to explain it:

In order to stand straight with your right foot and right shoulder touching the wall, your left leg has to push against the floor. This is necessary in order to move the upper body and your right shoulder against the wall. Because of the strain in your left leg it is impossible to move it away. If forced by someone else, you will fall towards the left, mainly because the **center of gravity** of your body is on the left side of your right foot, which would be the only support. In order not to fall, your center of gravity should be located exactly above the pivot point or support - in this case: your feet. After your left leg is knocked away, your body needs to move towards the right in order not to fall, but the wall prevents this.

3.1.14. THE CENTER-SEEKING PAPER

What you need: 1. A small piece of writing paper (1/8 of letter size). 2. A wide, shallow tray.



How to set it up:

1. Draw a small parallelogram (about 2x3 cm) with its diagonals on the little piece of paper.
2. Wet the parallelogram (not the whole paper) with water by letting droplets fall from your wetted index finger one at a time.
3. Fill the tray with water, lift the piece of paper carefully and let it float on the water surface.
4. Touch the tip of your index finger to the water on the parallelogram at a spot other than the crossing of the diagonals. What is the paper doing?

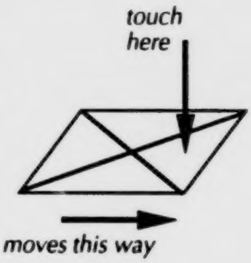
What questions to ask:

1. Why does the water not spread to the other parts of the paper?
2. What force keeps the water on the paper together?
3. When touching the wetted part of the paper near one edge, which way does the paper shape move to?
4. At what point does the finger end up above the paper shape?
5. What makes the wet paper shape move?
6. What makes the paper stop moving eventually?

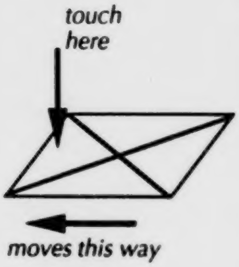
How to explain it:

The water drops on the paper are held together by **cohesive forces.** This is the reason why the water is not spreading to the other parts of the paper.

When the finger tip is touched to one side of the paper shape, it is pulled to the other side by a larger cohesive force (see Sketch A). When touching the opposite side, the movement of the paper goes opposite too (see Sketch B).



Sketch A

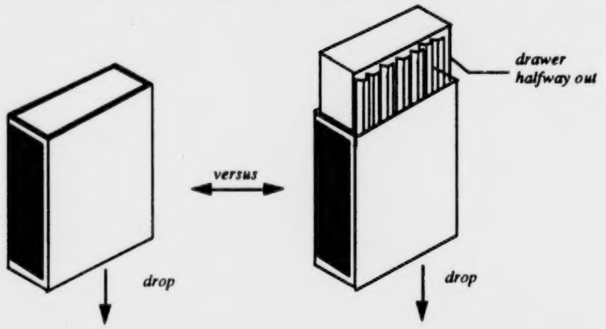


Sketch B

Whenever the paper stops moving, all **adhesive and cohesive forces are in balance.** It is also the center of gravity of the wetted shape. This can be used as a special way to find the center of gravity of an irregular shape.

3.1.15. THE STANDING MATCHBOX

What you need: 1. One full or almost full wooden matchbox.
If used for class activlty: 10-20 matchboxes needed.



How to set it up:

1. Distribute one matchbox per couple of students. Ask them to hold the box vertically above the table (about 15-20 cm above) and let go of the box. Then ask the question: "Can you drop it and leave it standlng up?" or "Can you drop the box without it tipping over?" Give them time to try it out. Anticipated answer: "Impossible!"
2. Then you say: "Remember, nothing is impossible!"
   Take the box, open the drawer about half way out, hold the box vertically with the drawer up, and drop it from about the same height.
3. If you do not succeed in the flrst two or three tries, lower the height. Ask tne students to try dropping the closed box ten times and counting the number of times it was left standing versus the half open box.

What questions to ask:

1. Why does the closed matchbox almost invariably tip over when dropped?
2. What makes the half open box more stable?
3. What did we do to the center of gravity of the box by pulling the drawer half way out?
4. What happens to the center of gravity at the moment that the half open box hits the table surface?
5. How do people usually lessen the impact when jumping off a high ledge or loft?

How to explain it:

As the matchbox is made out of cardboard, it is somewhat springy. Thus when dropped on a hard surface it is bound to bounce side ways, as it is almost impossible to let it land exactly flat on the smallest rectangular surface. Most of the times it lands on an edge or a corner of the box, and the box tips over. If the box was made out of clay, it would not bounce, it would actually **give** at the point of **impact** and stand up straight.

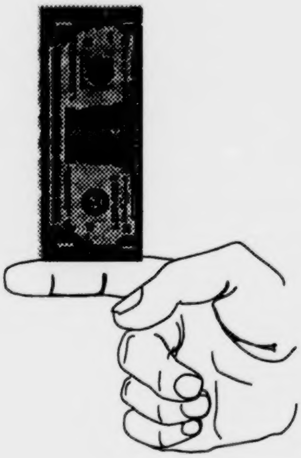
The half open box almost acts the same way as the clay cube. The outer sleeve acts like a cushion, as at the time of impact, the drawer, where most of the mass is, keeps sliding in further, thus breaking the fall. Its **center of gravity,** which is located in the center of the drawer, keeps moving in further at the point of impact. This is exactly how people break their fall when jumping off high places, by bending their knees just after or at the point of impact.

3.1.16. STAND A DOLLAR BILL ON YOUR FINGER

What you need: 1 , A crisp dollar bill , or any other strip of paper of the same size or somewhat larger.

How to set it up:

1. Take the crisp dollar bill and stand it vertically on the table top. Show the audience that it is pretty difficult to keep it standing for any length of time.
2. Ask the students: "How long do you think can I keep it standing on my stretched-out finger?"
   Anticipated answer: "About 2-3 seconds".
3. Now bend/curve the bill somewhat length-wise and place it on tip of the bill and balance it (move your finger quickly to the left if the tip of the bill moves left, and to the right as soon as the tip of the bill moves right).
4. Let the students measure the time now of how long you could keep the bill standing on your index finger.



What questions to ask:

1. How long can you balance tne dollar bill on your finger?
2. Is there a limit to the length of time you can balance it?
3. What keeps the bill from falllng over?
4. Would a longer or shorter strip of paper be easier to balance?
5. Would a wider or thinner (narrower) strip be easier to balance?

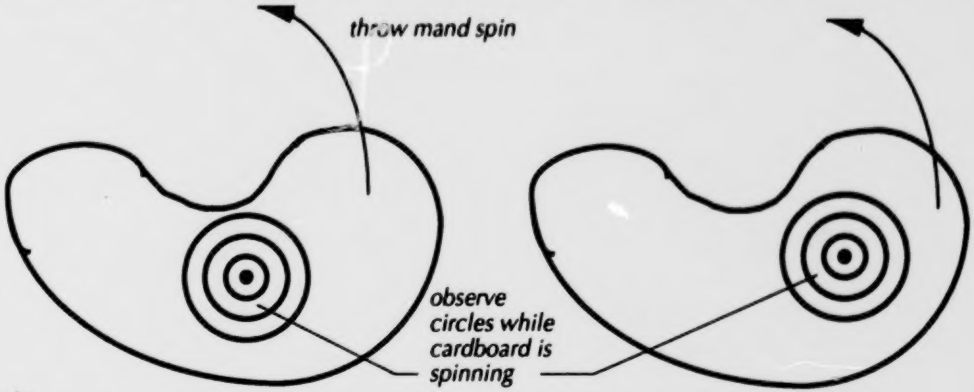
How to explain it:

This balancing act can also be performed with any sheet of writing paper, as long as there is a slight bend in the paper to make it stand rather stable on your hand (or finger). The larger the area of the paper, the higher the **air resistance** when moving it from left to right or the other way. There is a cushion of air surrounding it, holding it up, as it were. The taller the strip of paper, the higher the center or gravity of the piece, and thus the easier the balancing. The wider the strip of paper, the larger the surface area, and thus also the easier to balance it, as the air friction (or cushion) will keep it vertical.

In juggling acts where the juggler balances a vertical pole on his head, the more mass is carried at the top of the pole, the easier it is to balance the whole system. This is because the top end will then be more **inert,** and it is easier to move the bottom end without moving the top end, and thus to move and place the support point (**pivot**) under the center of gravity of the system.(see **Another Balancing Act - page**).

3.1.17. THE WOBBLING CIRCLES

What you need: 1. A piece of cardboard, a pair of scissors. 2. A drawing compass, a felt marker.



How to do it:

1. Cut the cardboard in a kidney shape.
2. Find the center of gravity of the cardboard shape by letting it balance on your finger and find the point where it balances: mark this spot.
3. Draw concentric circles around this spot with the compass and thicken the circles with the marker by drawing over the pencil circles.
4. Draw exactly the same concentric circles on the reverse side of the cardboard, but around a spot that is about 3 cm away from the center of gravity.
5. Have students now observe the following demonstration:

a. Let the cardboard piece spin vertically in the air, by flipping it upward holding the piece by one of its ends, (use wrist action when throwing) and catching it when it comes down.
b. Flip the board, so that the students would see the other side (be inconspicuous in doing this) and spin the cardboard again.
c. Let students observe and follow the circles while the cardboard is spinning in the air.

What to ask:

1. Why are the circles sometimes wobbling and sometimes staying steady?
2. How did I get the circles to wobble?
3. How can I find the center of gravity of the cardboard?
4. Around what point would an axe or hammer (with wooden handle) spin?

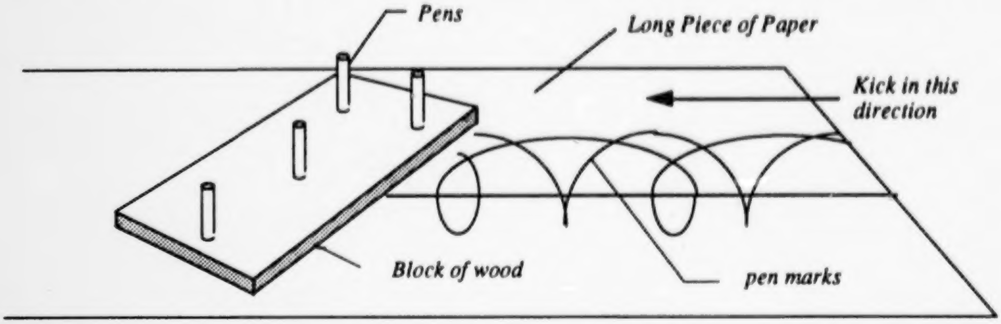
How to explain it:

Steps 1 through 4 of the procedure should be done before the demonstration without having the students observe it. **All objects spin around their center of gravity.** By drawing the concentric circles around the center of gravity on one side of the cardboard, the circles stay steady when the board is spun. When the other side of the board is shown to the students, the circles wobble, because it is off center and the circles actually spin around a point outside the circle's center making a wobbling motion.

When an axe or hammer with a wooden handle is spun in the air, it will also spin around its center of gravity, which is very close to the iron part of the tool. This makes the handle seem to swing out much more than the metal part.

3.1.18. KICK A STRAIGHT LINE

What you need: 1. A wood block (2x4" about 1 ft long) or any other shape.
2. Four ballpoint pens. 3. A long piece of newsprint paper (or brown wrapping paper).



How to set it up:

1. Drill three holes in the wood block: two at one end and one at the opposite end. The size of the holes should be such that the pens can be inserted rather tightly in the holes.
2. Insert three pens in the three holes, such that the point just sticks out on the other side of the board.
3. Now find the center of gravity of the total system by finding the balance point on the tip of your finger. Mark that point.
4. Drill the same size hole through this point and insert the final fourth pen (you can use a red one here) the same way (make sure that all four pens are evenly touching the table top).
5. Place the wood block with the pen points on the long stretched out paper in the hall way.
6. Kick the block of wood, such that you send it spinning down the hall over the paper (kick towards the end of the block). Observe the pen marks!

What questions to ask:

1. What kind of lines do you observe?
2. Why did only one line stay straight?
3. What kind of tracks would we get with only the first three pens inserted?
4. Would there be any difference in tracks if we eliminated one of the first three pens? (by retracting it such that the point does not protrude enough to make a track, but leave the pen in the hole).
5. What would happen to the straight line track if we took one of the first three pens completely out of the hole?

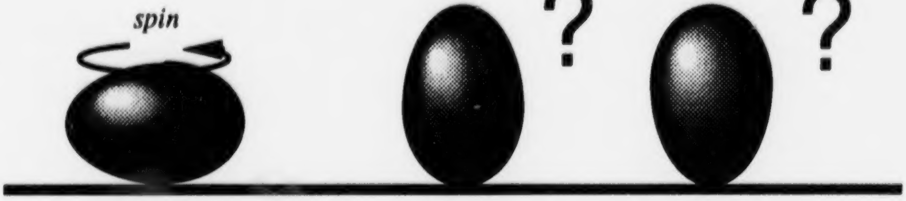
How to explain it:

This demonstration is another proof that **spinning objects spin around its center of gravity.** The fourth hole in the block of wood was made exactly in its center of gravity. By kicking the block against one end in the direction of the long piece of paper, it was spinning down the hall way around its **center of gravity.** Thus the fourth pen did not move side ways, and a straight line was obtained. Without this pen no straight line could be obtained.

If one of the first three pens is completely removed, the fourth pen actually would not be located exactly at the system's center of gravity anymore, thus the straight line becomes also a wobbly line.

3.1.19. STAND A RAW EGG ON ITS HEAD

What you need: 1. One raw chicken egg. 2. One hard-boiled chicken egg.
3. A piece of paper towel or handkerchief.



How to set it up:

1. Place both eggs on the table and ask students: "How can I tell which one of the two eggs is hard boiled, without breaking the eggs?"
2. Spin the eggs one at a time with the same force: which egg spins much easier and faster?
3. Ask a student to stand the raw egg on its head on the table (with a table cloth). If the table has no table cloth, place the egg on a paper towel, napkin, or handkerchief. **It is almost impossible to do this!**
4. Now hold the raw egg firmly in your hand and shake it vigorously for about 30 seconds, then place it immediately on its head on the table (on the paper or cloth). Voila! It stands!

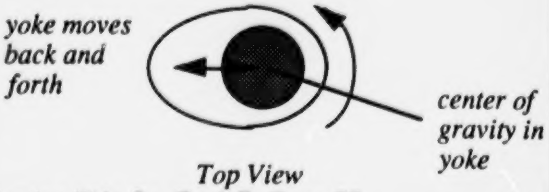
What questions to ask:

1. Why did the hard-boiled egg spin faster than the raw egg?
2. How else can we tell which of the two eggs was the raw one?
3. Where is the center of gravity of a raw egg located?
4. What was achieved by shaking the raw egg vigorously?
5. What made it possible for the raw egg to stand on its head?
6. Would it be possible to stand the hard-boiled egg on its head?
7. Would you expect it to be harder or easier to stand the hard-boiled egg on its head, as compared to the raw one?

How to explain it:

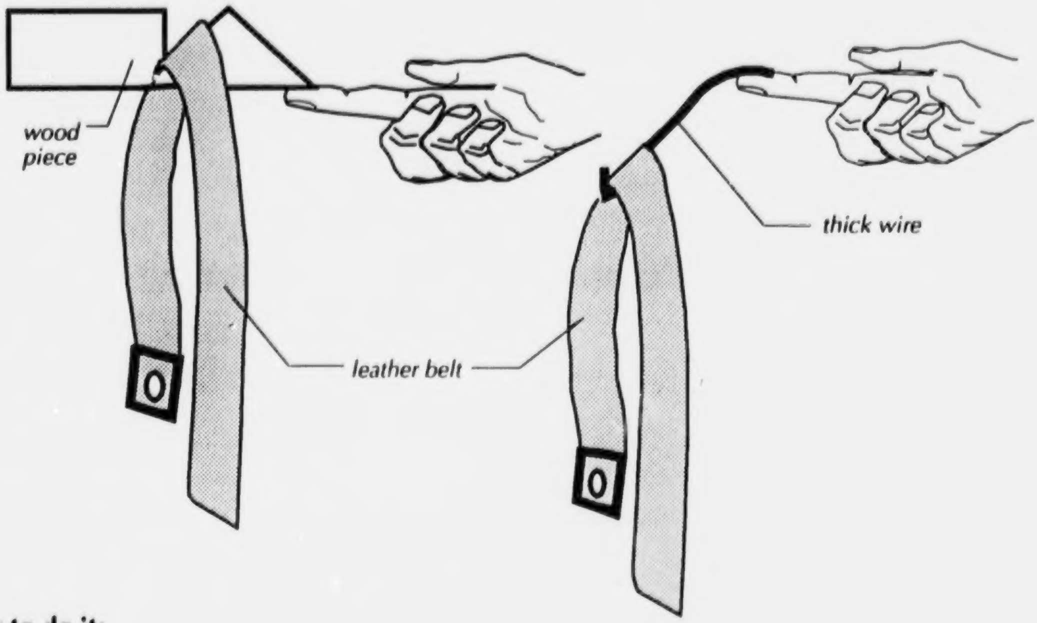
A chicken egg consists of a yoke, egg white, and the shell. The yoke is where most mass is concentrated and thus the **center of gravity** of the egg is close to the yoke or in the yoke. When a raw egg is spun, the yoke swings out (see Sketch) and swings back to the other side, thus slowing down the rotation. When the egg is hard-boiled, the mass inside the egg is solid, thus the **center of gravity** is stationary and the egg can spin fast around this point.

Shaking a raw egg vigorously will make the yoke more mobile or movable inside the egg-white, thus after shaking, the yoke can move down lower in the head of the egg. This lowers the **center of gravity** and the egg is therefore much more **stable.** Try to stand the egg on its smaller end: it's possible too! - because the yoke can now move down to the smaller end too!



3.1.20. THE FLOATING BELT HANGER

What you need: 1. A small piece of plywood cut in the shape pictured in sketch or a piece of coat hanger bent in an S shape. 2. A leather belt.

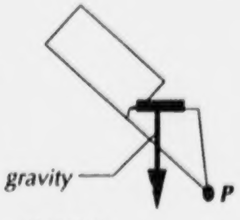


How to do it:

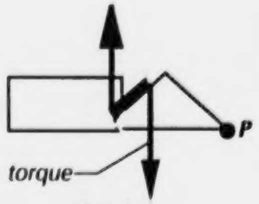
1. Ask students: "What will the wood piece do if I put it on my finger like this (see sketch but without belt) and let go of it?" (Anticipated answer 'it will fall').
2. Let go of the wood piece or wire and let it fall.
3. Now hang a leather belt on the incline of the plywood piece or at the end of the iron wire (make sure that it balances).
4. Hold both ends of the belt in your right hand and pull at it—the belt is held up!

What to ask:

1. Why doesn't the belt fall?
2. Which forces are working on the piece of wood?
3. In what position is the belt only exerting a downward force?
4. Can belts made of other materials also be hung on the 'hanger'?
5. How steep does the incline have to be for the belt to stay up?



Sketch 1



Sketch 2

How to explain it:

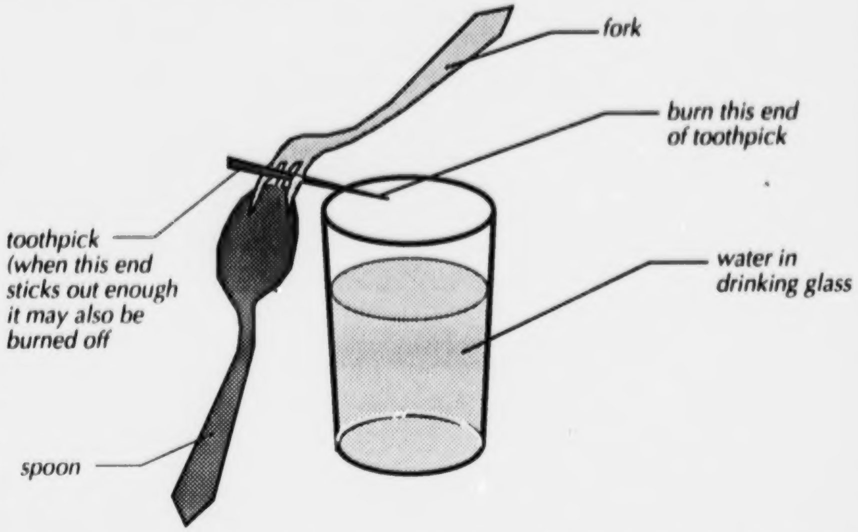
At this position (Sketch 1) the belt is exerting only a downward force and no other. The incline is now a horizontal ridge. As soon as the shape is turned around point P in a counterclockwise direction, the belt hangs on an incline. Now it exerts more than a downward force. It now exerts a **torque** in a clockwise direction. This means that **two equal but opposite forces that tend to rotate** are now working on the wood piece. The force which is exerting upward farther away from the pivot point P is the one that holds up the belt. The harder the pull downward on the belt, the larger this torque becomes, and thus the larger the force upward.

3.1.21. THE FORK AND THE SPOON ACT

What you need: 1. A fork and spoon (regular dinner silver).
2. A flat toothpick, a wooden match, regular matches, and a drinking glass.

How to do it:

1. Attach the spoon to the fork by pushing it in between the teeth.
2. Place a toothpick between two of the fork's teeth and let the system balance from the toothpick resting on the rim of a drinking glass (see sketch).


fork
burn this end of toothpick
toothpick (when this end sticks out enough it may also be burned off
water in drinking glass
spoon

3. Once the spoon and fork are in balance on the glass rim, dramatize by burning off both ends of the toothpick.
4. Now repeat points 2 and 3 with a wooden match. What happens?

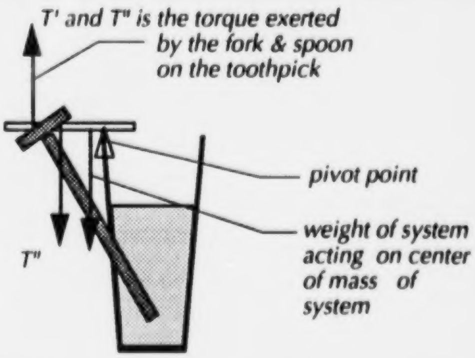
What to ask:

1. What keeps the toothpick floating horizontally beyond the glass rim?
2. How far in or out can the toothpick protrude beyond the glass rim?
3. Why did the burning of the toothpick stop exactly at the fork and/or the glass rim?
4. What forces are working on the toothpick?
5. What other objects could be used in place of the toothpick?

How to explain it:

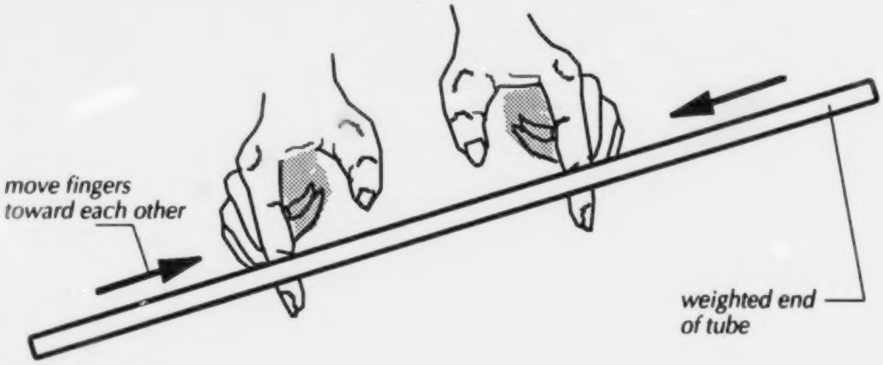
The spoon and fork are hanging almost on their sides from the toothpick and this is the reason why they are actually exerting a **torque** on the toothpick (see sketch on right).

The burning of the pick stops exactly at the glass rim, because the heat of the flame is suddenly **absorbed** or **conducted away** by the glass, and the temperature drops below the wood's **kindling point.** When the toothpick is protruding on both ends, it may be burned on both ends. The flame at the fork end will be extinguished for the same reason (the heat of the flame will be absorbed or conducted away by the metal of the fork).


T' and T" is the torque exerted by the fork & spoon on the toothpick
pivot point
weight of system acting on center of mass of system
T"

3.1.22. THE WEIGHTED PIPE

What you need: 1. A 1 m long, metal, water pipe (weighted at one end with lead).
(A hollow cardboard tube may be used with a weight stuffed at the end).



How to do it:

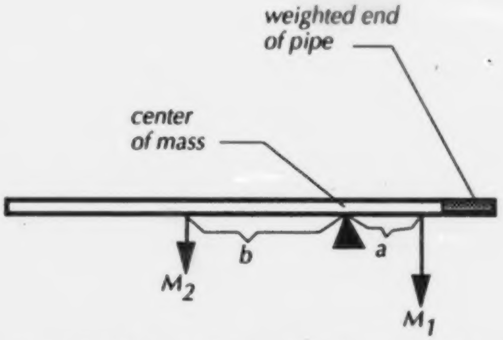
1. Take the water pipe (or cardboard tube) and stuff one end with empty toothpaste tubes (do not show this to the students).
2. Place the weighted tube on your two stretched out forefingers at the far ends of the tube.
3. Move your hands slowly towards each other and ask: "W here will my fingers meet?" (they will not meet in the center of the pipe).

What to ask:

1. Why did the fingers not meet at the center of the tube?
2. Holding the tube at the center of mass, which end of the tube is heavier? The short end or the long end?
3. Where are the actual forces working on the pipe in relation to the pivot point, which is the center of mass of the whole pipe?
4. Where would the fingers end up if the pipe were not weighted?

How to explain it:

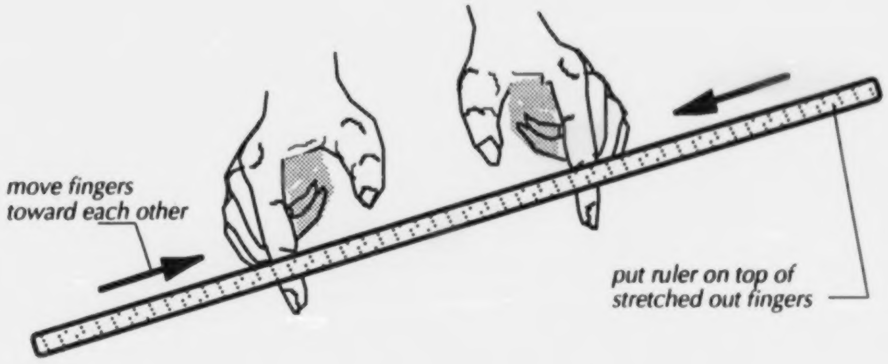
Under the weighted pipe, the sliding fingers will end up under the **center of mass** of the whole pipe, which is off center, more shifted towards the heavy end. The short end of the pipe is heavier than the long end, yet they are in balance, because the larger force (M_1) has a shorter arm (a) and the smaller force (M_2) has a longer arm (b) in relation to the pivot point (center of mass—see sketch on right).



When the object is in equilibrium, **all clockwise couples** ($M_1 \times a$) **equal the sum of all counter clockwise couples** ($M_2 \times b$).

3.1.23. THE GOLDEN MIDDLE

What you need: 1. A meter stick (one for each pair of students). 2. A weight (200 g) or rock.



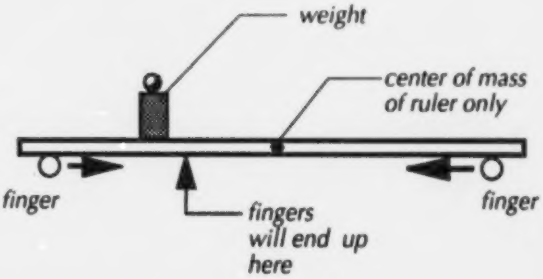
How to do it:

1. Take the meter stick and place it in any position on your two stretched out forefingers.
2. Move the fingers towards each other: they always end up in the middle of the ruler.
3. Distribute the meter sticks to each pair of students and let them try to do the event themselves.
4. Place a weight or rock at 25 or 75 cm from the end, and let students bring their fingers together. Where do they end up?

What to ask:

1. Why do the fingers always end up in the middle of the ruler?
2. Does it matter where the two fingers are placed initially?
3. Which finger moves more: the one closer or farther from the center?
4. What is keeping the finger closer to the middle from moving?
5. Where is the center of gravity of the ruler (without the weight)?
6. Between which finger and the ruler is there more friction: the one closer or farther from the middle?

How to explain it:



Since the **center of gravity (center of mass)** of the ruler is in the middle of the ruler, it presses more on the finger which is closest to the middle. This causes a greater **friction** for this finger when moving it. So the finger which is farther from the middle would move first, until both fingers are the same distance from the middle, then both fingers move at the same rate towards the middle.

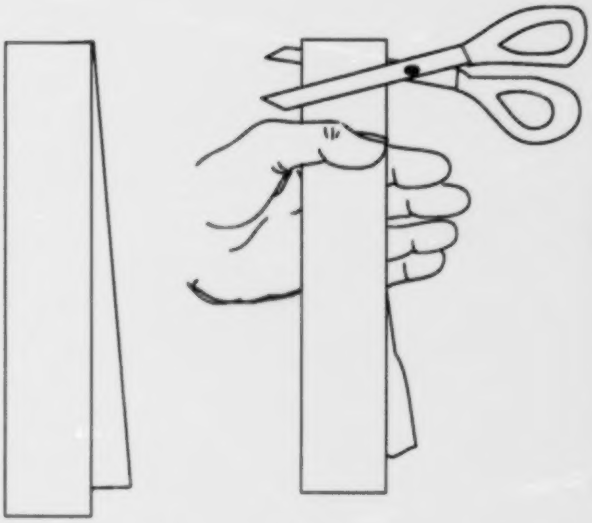
If a weight was placed at one end of the ruler, we will notice that the fingers will end up very close to the mass or weight, or rock placed on the ruler. This is because the center of gravity of the whole system (stick & weight) is shifted.

3.1.24. THE MAGIC STRIP OF NEWSPAPER

What you need: 1. A 3-4 cm wide strip of newspaper (about 30 cm long doubled). (unfolded strip: 60 cm long). 2. Rubber cement, talcum powder (or any kind of flour).

How to set it up:

1. Unfold and lay the paper strip on a newspaper.
2. Cover one side of the strip with a layer (preferrably 2 layers) of rubber cement and leave to dry.
3. Sprinkle some powder or flour over the dried rubber cement and wipe the excess off the strip (make sure all of the paper is covered with the powder).
4. Now you are ready for the demonstration: show the audience the paper strip.
5. Hold the strip close to the fold. Take a pair of scissors and cut about 2 cm off from the top, hold one end of the strip and hold it up: **it is one whole piece again!**
6. This cutting procedure may be repeated several times. Let students come up with a **hypothesis** of how this can happen.



What questions to ask:

1. What makes the strip whole again?
2. After cutting, is the strip actually whole?
3. What is the function of the powder or flour?
4. What is the function of the rubber cement?
5. What other material can we use besides rubber cement?
6. What would happen if you cut the strip in an angle?
7. What hypotheses can you come up with to explain this event?

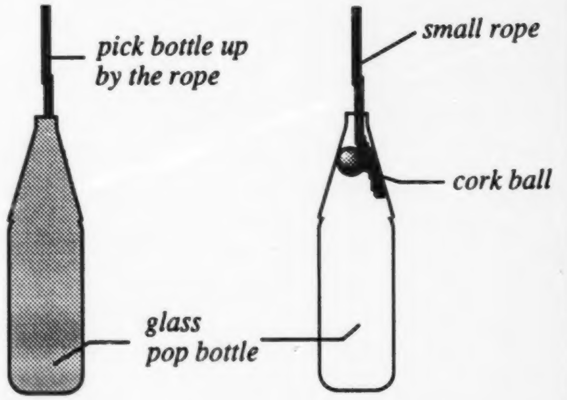
How to explain it:

The function of the rubber cement is to make the two cut strips after cutting the long strip with the scissors, to **adhere** to each other. The powder or flour spread on top of the rubber cement makes the surface smooth and not sticky. The two rubber cement covered surfaces can then be placed on top of each other without sticking to each other. At the edge where the paper has been cut with the scissors, however, the pressure was high enough that just the edge and **only the edge** is sticking to each other. The two cut pieces then look like one whole piece again.

A variation to this demonstration is to cut both the top end and the bottom end, separate the top end and let it hang from one of the strip ends or leave both ends connected and show a loop. It is an excellent demonstration to make the students think and develop their imagination.

3.1.25. THE INVISIBLE GLUE

What you need: 1. A plastic or glass bottle with a long tapered neck. 2. A piece of thin rope, a smallcork.



How to set it up:

1. Preparation: Make a small ball (sphere) of the cork by cutting and filing until it just fits in the bottle neck (it should be a tiny bit larger so that you have to force the ball cork in).
2. Push the ball cork in the bottle and cover the bottle with paper or paint the whole bottle (so that it becomes opaque).
3. Now you are ready for the demonstration: Hold the rope in your hand and say to the audience: "I have some invisible glue in this small bottle" (an empty small bottle), "I'll dip the end of this rope in it and let it stick to this large bottle".
4. Do the dipping and let the rope slide inside the opaque bottle, turn the bottle upside down, pull slowly at the rope until you feel some resistance, then turn the bottle rightside up, keep the tension in the rope, and let the bottle hang from the rope. Let students make inferences/hypotheses.

What questions to ask:

1. What hypotheses/inferences can you make to explain the event?
   After students know about the cork ball:
2. What is the function of the cork ball?
3. Why does it have to be somewhat larger than the bottle neck?
4. What other material can we use instead of cork?
5. How can we get a regular cork that went in, out of a wine bottle?
6. What is the principle or property made use of in this demonstration?

How to explain it:

The reason why the bottle can keep hanging from the loose rope is ***friction.*** When the bottle is turned upside down, the cork ball rolls in the bottle neck and pinches the rope against the side of the bottle. By pulling the rope, it pulls the cork in even tighter as the neck is tapered. The friction between the rope and the cork is greater than that between the glass and the cork, so the cork gets pulled a little farther in the neck, thus pinching the rope. The rope can be pulled out of the bottle with a sharp yank. In place of the cork we can also use a rubber ball. A marble of a slightly smaller diameter than that of the bottle neck may also be used, but the rope has to be quite a bit thicker.

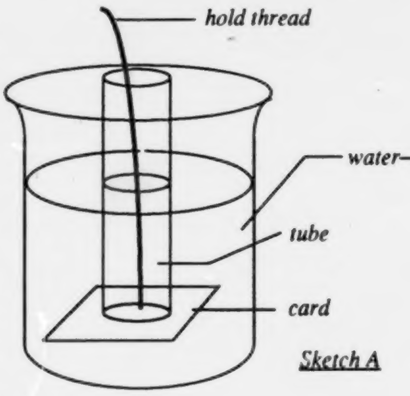
Making use of the same principle, we can take a cork out of an empty wine bottle with a cloth napkin (serviette). Get one of the corners of the napkin inside the bottle neck, let the cork roll over the napkin, slowly pull the napkin until the cork tightens in the neck, then pull hard on the napkin; the cork will pop out! (see **HOW TO GET THE CORK OUT II**)

3.1.26. THE CARDBOARD BOTTOM

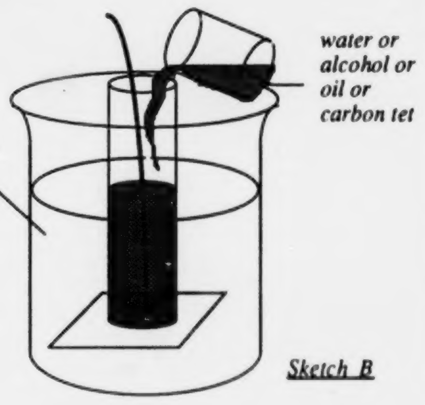
What you need: 1 . A glass or plastic open tube (open at both ends). (about 2-3 cm diam and 10-15 cm long) 2. A glass or other transparent container (4-500 ml beaker).
3. A stiff paper (or plastic) card, tape and thread, small beaker.

How to set it up:

1. Tape the end of tne thread to the middle of the card, let the other end of the thread fall through the open tube, and hold the card by the thread against the bottom end of the tube (see Sketch A).



Sketch A



Sketch B

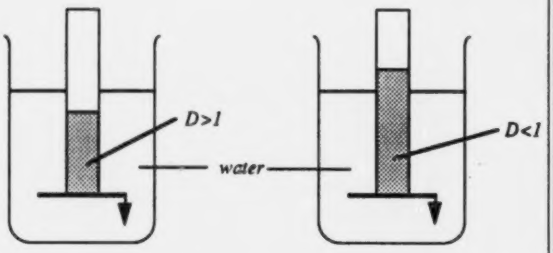
2. Lower the tube vertically in the water filled glass container, while holding the card against the bottom of the tube, until about half the length of the tube is immersed.
3. You can now let go of the thread (the card will be kept in place), and pour carefully and gradually some water in the tube from the small beaker (see Sketch B).
4. Continue to pour water in the tube until the moment that the card falls away from the tube.

What questions to ask:

1. At what point does the card fall away from the tube?
2. What kept the card in place even after releasing the thread?
3. Why did the card not fall off even after pouring a little water inside?
4. Would the card fall off if we poured alcohol or oil in the tube instead of water? How about pouring carbon tetrachloride?
5. In order to pour the same amount of carbontet as the amount of water in the tube, what do we have to do with the tube (so the card would stay)?
6. Is it possible to pour carbontet up to the level of the water (without the card to fall off)?
7. What liquids can be poured in the tube up to the water level, without the card falling off?

How to explain it:

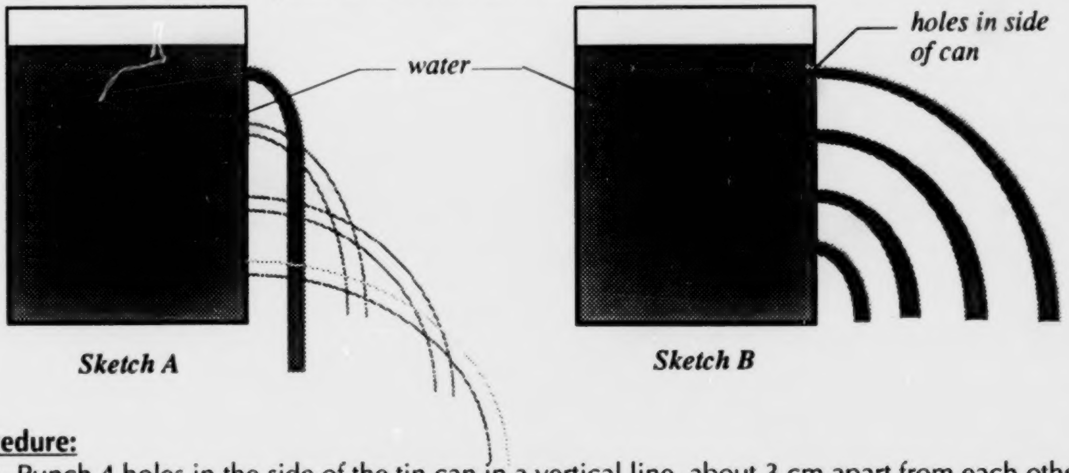
Water pressure is exerted equally in all directions. Tne card falls off from the bottom of the tube only when the water column above it is flush (same height) with the water level outside the tube.



Lighter liquids (those of lower density) can stay up even higher above the water level, as it would take more of it to make the same weight of water. Heavier liquids will drop the card sooner. It is therefore impossible to fill the tube up to the water level with liquids of densities greater than 1. (see Sketch on right).

3.1.27. THE SQUIRTING WATER HOLES

Materials: 1. A large tin can (juice can) or milk carton. 2. A medium size nail, and bucket or sink.



Sketch A *Sketch B*

Procedure:

1. Punch 4 holes in the side of the tin can in a vertical line, about 3 cm apart from each other, the lowest one also about 3 cm from the bottom (make the holes the same size and shape).
2. Hold the can above the sink or bucket, have one of the students (X) cover the four holes with his/her fingers, and fill the can full with water.
3. Now ask the students: "Which hole will squirt water the farthest when student X takes away his/her fingers?", and let student X release the flow of water. Compare prediction and result.

Questions:

1. Which hole squirted the water out the farthest? In other words: which of the two sketches above is the correct one, A or B?
2. What factor determined the squirt distance from the can?
3. What are other variables that might influence the squirt distance?
4. How would different sizes of holes in the can compare?
5. Would the diameter of the can influence the squirt distance?
6. Would the height of the can or the height of the water level have more influence on the squirt distance?
7. How would water compare to alcohol or oil in the squirt distance?

Explanation:

The correct sketch above is Sketch A, showing that the top hole in the tin can would give the shortest squirt, and the lowest hole the farthest. This immediately shows that the height of the water level is influencing the squirt distance. The more viscous the liquid, the less the squirt distance, this means that oil would not squirt as fast as compared to water. A smaller hole compared to a large hole, with all other variables held constant (the same), will give a larger squirt distance.

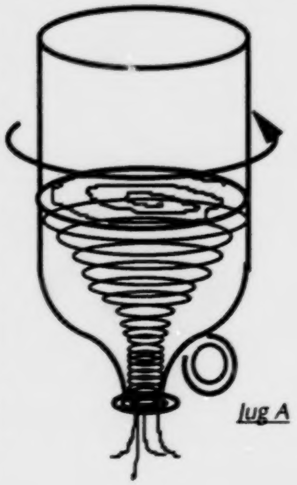
Whether the liquid inside the can will squirt out at all, depends on the **liquid pressure** inside the can. This is caused only by the height of the liquid level above the point of puncture. This in turn is caused by the weight of the liquid or the gravity force. If there were no gravity working on a completely closed juice can, like in a satelite capsule, puncturing it at any place would not make the juice come out.

3.1.28. THE OUTPOUR RACE

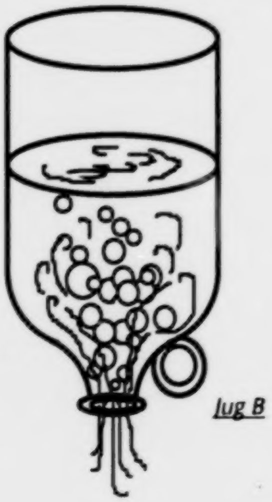
What you need: 1. Two identical gallon jugs (with narrow neck). 2. Sink or buckets.

How to set it up:

1. Fill both jugs three quarters full of water. Place them next to each other and show the students that they have the same amount of water.
2. Ask two students to come forward to pour the water out as fast as they can into the sink or the buckets (student A already got instructions beforehand to swirl the water before pouring it out: *Hold your palm over the opening while holding the jug upside down, make a turning motion to swirl the water until it forms a vortex, then let go of your palm covering the opening).*
3. The rules are: The pourers may do anything to the jug before and during the pouring of the water (except break it).
4. Have two other students time the outpour with a stopwatch or by putting their hands up as soon as all the water has poured out.



Jug A



Jug B

What questions to ask:

1. Which jug invariably wins? Jug A or Jug B?
2. What does the swirling do to the water level?
3. Why does it take so long for water to pour out of the jug?
4. What is trying hard to get into the jug while pouring the water out?
5. What is usually the cause of the vortex formation in the water surface?
6. What would you expect the pressure to be in the center of a vortex, higher or lower than the periphery?
7. In what places in nature can you find vortex formation?

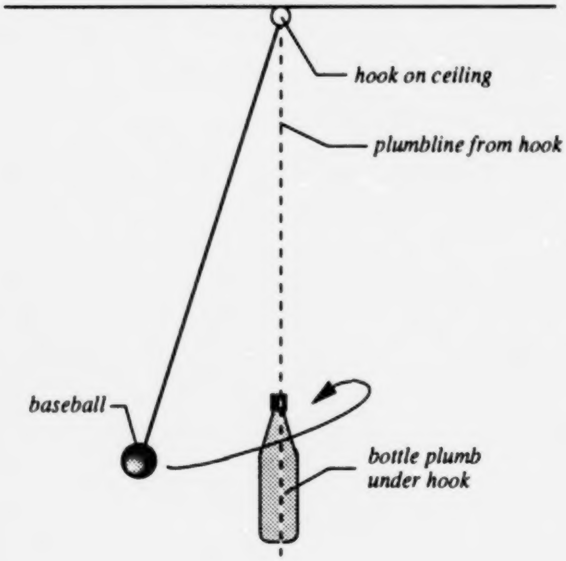
How to explain it:

By moving the jug in a clockwise or counter-clockwise rotation before pouring the water out, a **vortex** is formed, indicated by a funnel-like shape of the water surface. At that moment the center of the vortex has a much **lower pressure than the outer areas,** making it easier for the air to come into the jug. Thus the water will pour out faster. Keeping the water swirling while the water pours out will make it pour out steadily as the vortex is maintained.

Vortex formation is found in nature in fast flowing rivers, where the water has to go around a corner or around a large rock. In pools below a waterfall we can also find vortex formation, caused by strong currents of water. As the pressure in the center of the vortex is lower than its surrounding outer area, swimming near a waterfall can be quite dangerous. When caught in a vortex, the best thing to do to get out of it would be to go with the flow, which is downward and come up to the surface at another spot - *do not struggle to swim up to the surface as this will keep you under water!.*

3.1.29. HIT THE BOTTLE ON THE BACK SWING ?

What you need: 1. A soft ball or base ball. 2. A thin string & hook or nail.
3. An empty coke bottle.

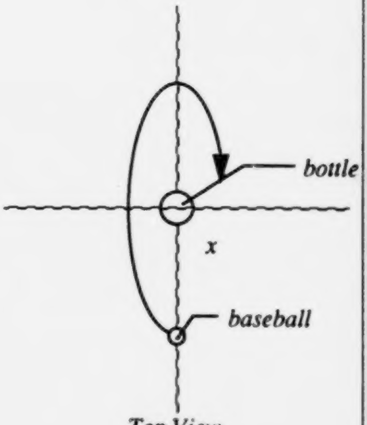


How to set it up:

1. Tie the base ball to the string and hang it from the ceiling in such a way that it hangs about 2 cm higher than the bottle above the floor (do not make a knot in the string).
2. Let the ball hang very still and place the bottle plumb under the ball. Mark the position of the bottle on the floor with chalk.
3. Now lower the ball until it is about 10 cm above the floor, then put a permanent knot in the string (at the hook on the ceiling).
4. Bring the ball out towards you (about 2-3 m away from the bottle), swing the ball to the side of the bottle and try to hit the bottle with the ball on the back swing.

What questions to ask:

1. Is it possible to hit the bottle on the back swing?
2. Why does the ball always swing back on the other side?
3. What is the energy of the swinging ball transformed into?
4. Will the ball eventually hit the bottle when it is allowed to swing more than once?
5. How should we swing the ball to obtain the least number of swings to hit the bottle?



Top View

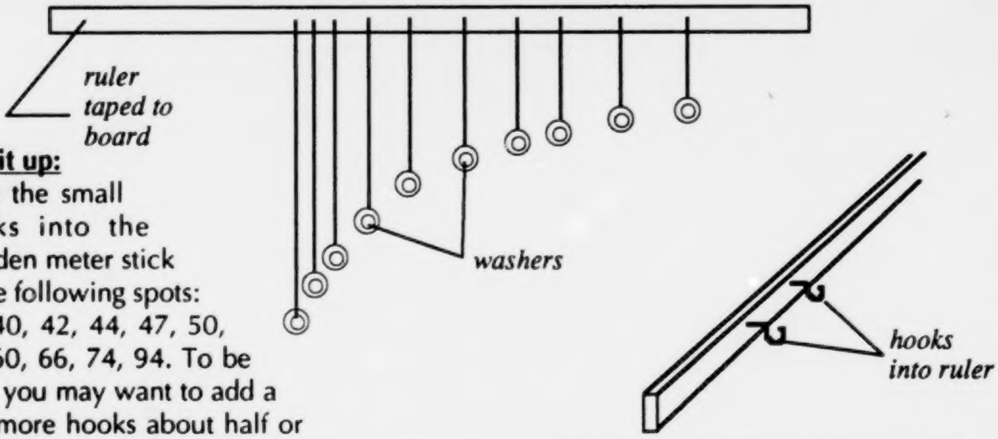
How to explain it:

The energy of the pendulum is **transformed into heat** at the point of attachment of the pendulum and in the air as **friction**, which is very small. The **amplitude** or height of the swing is therefore almost the same for the first few swings.

When looking from the top of the pendulum and the bottle, we can decompose the movement of the pendulum along axes X and Y. As the swing stays almost constant along both axes, the ball can not hit the bottle on the back swing (for the first few swings). After a while the ball will fall back to the vertical position and eventually hit the bottle.

3.1.30. HOW MANY SWINGS CAN YOU GET ?

What you need: 1. Fifteen washers (for a class of 30). 2. Thin string or strong thread, and scissors. 3. Wooden meter stick, a dozen small hooks (to place in ruler).



How to set it up:

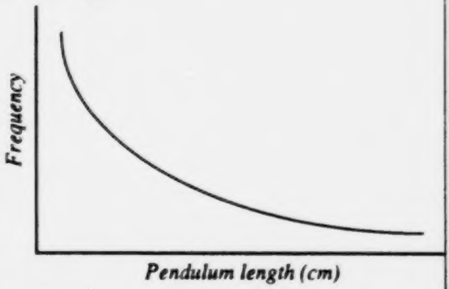
1. Place the small hooks into the wooden meter stick at the following spots: 39, 40, 42, 44, 47, 50, 54, 60, 66, 74, 94. To be safe, you may want to add a few more hooks about half or one cm away from each of the above points, then tape the ruler against the board (up high).
2. Tie a string to each of the 15 washers and make a knot at the washer and another knot the following lengths away: 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, and 10 cm, and cut the string off 2 cm above this last knot, and make a small loop (to hang the pendulum on the hook).
3. Give each pair of students one pendulum. Let one student hold the pendulum with a steady hand, and let the other count the number of swings (whole periods) per minute (count the number of times it comes back to your hand in 30 seconds, then double it). Let them do this two or three times and take the average of the value.
4. Once they have the number, let them come to the board and hang their pendulum at the correct spot on the ruler (similar to plotting length of pendulum against frequency of swings).

What questioins to ask:

1. Which of the pendulums got the most number of swings?
2. What determines the number of swings per minute of a pendulum?
3. Would a different/heavier pendulum bob affect the frequency of swings?
4. Would a thinner or heavier string make a difference?
5. What are other variables that would affect the number of swings?
6. Which of the pendulums could be used as a timer?

How to explain it:

This activity is especially effective to demonstrate that the number of swings per minute **(frequency)** in a pendulum depends solely on the length of the pendulum. It is independent of the mass of the bob.

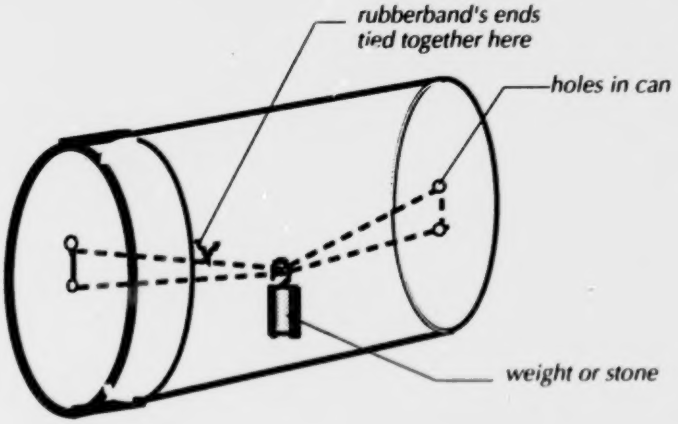


Variables like air friction, friction of the suspension construction, movement of the suspension point (in our case whether the student has a steady hand or not), may have the same influence on the slowing down of the pendulum and thus on the number of swings.

When plotting the number of swings per minute or frequency against the length of the pendulum, we will get a very similar parabolical curve as the one on the board.

3.1.31. THE MAGIC COME-BACK CAN

What you need: 1. A tin can with an opaque lid.
2. A thick, long rubber band and a short piece of string. 3. A weight or stone.



How to do it:

1. Make two small holes in the bottom and also in the lid of the can about 2 cm apart.
2. Cut the rubber band and push it through the holes, and tie the loose ends together inside the can (see sketch).
3. Tie a short piece of string around the weight or stone and tie the other end of the string to the center of the rubber band (do not let the weight or stone drag on the side of the can).
4. Place the lid back on the can, and you are now ready for the demonstration: Roll the can on a horizontal plane (the table top) and it comes rolling back!
5. Wind the rubber band up first, and let it roll uphill on an inclined plane.

What to ask:

1. Why did the can roll back (or roll uphill)?
2. What is the purpose of the rubber band?
3. What else is inside the can besides the rubber band?
4. How is the construction inside the can?

How to explain it:

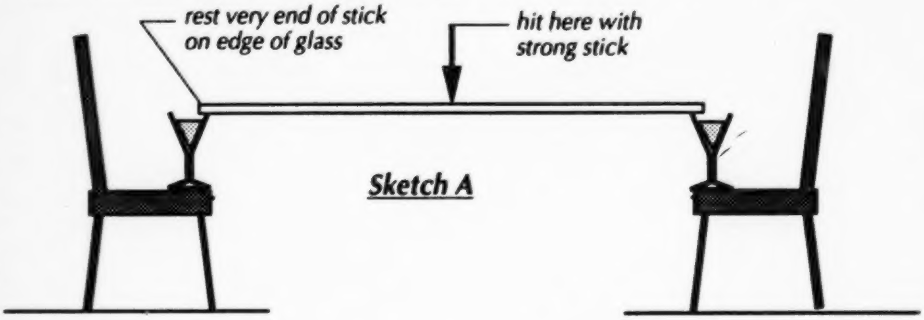
The purpose of the rubber band is to provide the rolling-back action. The weight or stone holds the rubber band stationary in the center of the can, so that when the can rolls, the rubber band twists itself, building up a **latent force** inside it, and when it untwists itself the cylinder rolls back. It can even roll up not too steep an incline.

This demonstration is quite suitable for a **black box** activity, where students have to figure out what is inside the can that makes it move, without looking inside it (exercise on inferring). A "black box" is used for a model of a model of an atom, where we can do something to it but not actually see inside the structure.

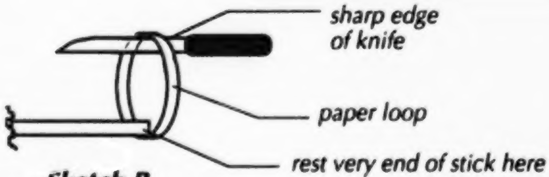
3.1.32. THE INCREDIBLE STICK

What you need: 1. A thin and long pine stick (2 m x 1 cm x 1/2 cm)/ 6' x 1/2" x 1/4"..
2. Two wine glasses or small beakers. 3. Two sharp kitchen knives & masking tape.
4. Two pins, a thick meter stick (or other strong stick).

How to do it:


rest very end of stick on edge of glass
hit here with strong stick

Sketch A



Sketch B

1. Push the pins into each end of the wooden stick.
2. Place the wine glasses or the beakers each on the edge of a chair or table, space them 2 m (or 6 feet) apart, and let the long wooden stick rest on the rim of the glasses suspended from the pins (see Sketch A).
3. An alternative would be to suspend the wooden stick on two thin paper rings hung on the sharp edge of the kitchen knives (taped against the back of two straight-back chairs—see Sketch B).
4. Hold the strong meter stick like an axe over your head and give the long horizontal stick a sharp blow in the center of its length.

What to ask:

1. Why did the beakers not break or fall? (for alternative A)
2. Why did the paper rings not tear? (for alternative B)
3. Was the force exerted on the center of the stick large or small?
4. How did the two broken pieces of wood move when they were hit?
5. Around what point do rotating objects move?

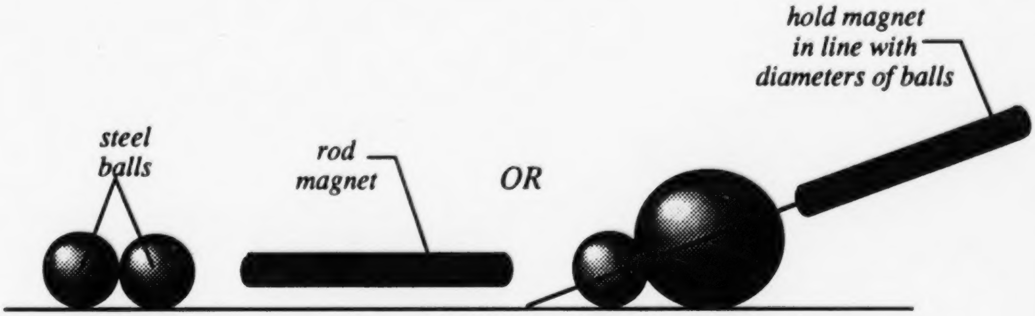
How to explain it:

The force of the blow was so **sudden** in the center of the wooden stick, that it broke before the force could be exerted on the paper rings or on the glass rims. The descending cudgel hits the center of the stick with such a great and sudden force that the center part descends and breaks. The two broken pieces are actually being **suddenly rotated**, one in a clockwise and the other in a counterclockwise direction. As **rotating or spinning objects rotate around their center of gravity,** the far ends of the long stick actually move slightly upwards, as the two pieces start rotating. The result of the blow is spectacular: the center of the stick falls victim to the **sudden influx of energy,** whereas the ends remain pretty well stationary or they move even more slightly upwards.

3.1.33. IS THE BALL REPELLED ?

What you need: 1. A strong rod magnet (or horseshoe magnet).

2. A small steel ball and a larger steel ball or two small identical steel balls.



How to set it up:

1. Show to the students that the two steel balls are both attracted by the strong magnet, and that both can easily hang on to the magnet.
2. Place the two balls on a smooth surface, next to and touching each other.
3. Approach the balls slowly with the magnet from a direction which is in line with the two diameters of the steel balls (if one ball is larger than the other, approach the larger ball with the magnet).
4. Ask: "What made the second ball move away from the first one?" A clue: if the magnet is not held in line with the extension of the two diameters, the second ball will not be moving away!

What questions to ask:

1. What would the balls do when they are approached by the magnet in an angle to the two diameters?
2. What would the balls do when they are approached from the smaller one (in case of two different sized balls)?
3. What would you expect the balls to do when using an overly strong magnet? Would they behave the same way?
4. How close does the magnet have to be before the balls are attracted?
5. Why do the two balls have to be touching each other? What would happen if they were not?

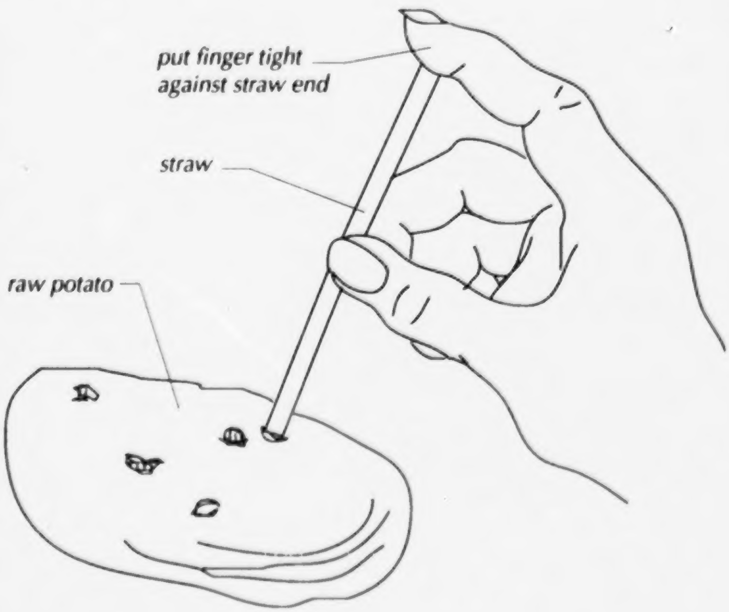
How to explain it:

The first hypothesis that an observer will form when seeing the second ball moving away from the first is, that it does this because it is repelled by the magnet somehow (by a change of polarity, which is completely erroneous!).

The actual explanation is that both balls are attracted by the magnet and at the time of impact the second ball is bounced back because of the **momentum** it has and the **elasticity of steel metal.** It moves away out of the magnetic field and is thus not attracted any more by the magnet. This bounce will not occur when the magnet is not held in line with the two diameters of the balls. An overly strong magnet will hold both balls in its magnetic field and the bounce will also not occur.

3.1.34. PIERCE A POTATO WITH A STRAW ?

What you need: 1. A large raw potato. 2. Two regular drinking straws.


put finger tight against straw end
straw
raw potato

How to set it up:

1. Hold one straw in your hand and push it against a hard surface, like f.i. the table surface and show the students that the straw is bending/folding.
2. Now hold the large potato in your left hand and the straw in your right (when you are right handed) with the index finger tightly pressed against the end opening of the straw (see Sketch on left)
3. Pierce the potato with one forceful stroke of the right hand. The straw goes right through the potato! This may be repeated.

What questions to ask:

1. Why does the straw bend when pushed against a hard surface?
2. What is the purpose of holding the forefinger tightly pressed against the end of the straw?
3. What would happen if the forefinger was not held there?
4. What is inside the straw at the moment that it hit the potato?
5. Would the pressure inside the straw be higher or lower than the atmospheric pressure?
6. What are other examples where a higher pressure of air or water inside the object would make it more rigid and strong?

How to explain it:

The purpose of placing the forefinger tightly against the end of the straw is to prevent the air inside the straw from escaping. At the moment that the straw hits the potato, the air inside the straw is compressed and the **higher pressure makes the straw rigid and strong.** The flexible straw then acts like a solid spear and penetrates the potato very easily. If the forefinger was not placed at the end of the straw, it would just bend when hitting the potato with it, just like it did when hitting the table top with it.

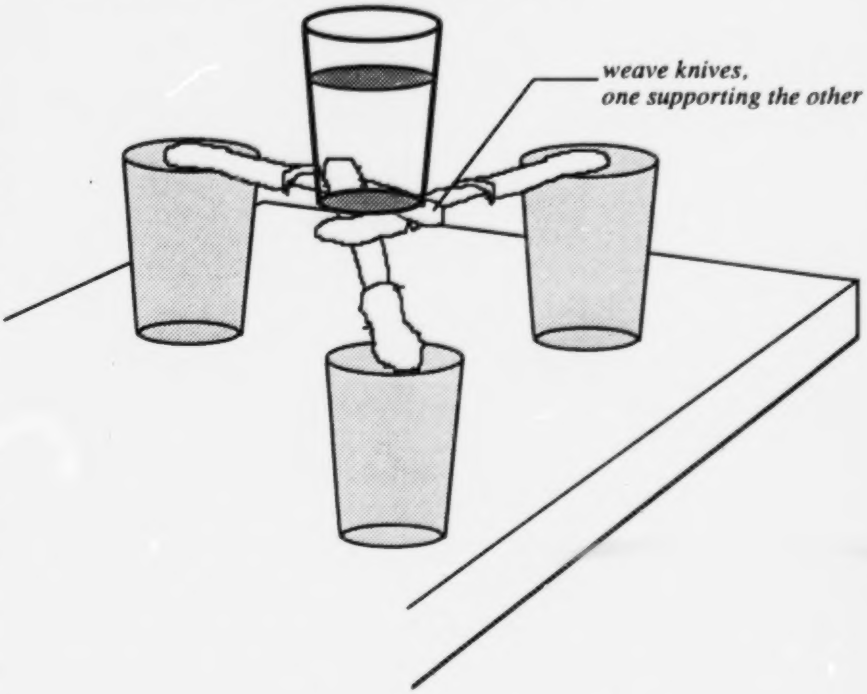
Other examples where a higher pressure of air makes the object rigid are: bicycle and car tires, inflated plastic or canvas beds and toys. Higher pressure of water inside the fibers and capillaries of plant tissue makes them more rigid and strong: fresh looking plants that are properly watered as compared to limp and drooping leaves because of water shortage.

3.1.35. THE LOOSE KNIFE SUPPORTS

What you need: 1. Four regular drinking glasses. 2. Three table knives.

How to set it up:

1. Place the three glasses in a triangle configuration on the table a little further than a knife long span away from each other.
2. Ask the audience: "How can I support the fourth glass in the middle of the other glasses at glass-height above the table with the three knives?"



3. Anticipated answer: "It s impossible!"
4. Give a clue: "Let one knife support the other!"
5. After everybody gives up: weave the knives as shown in the sketch above, and a strong support is created, which can hold the fourth glass quite easily. You may even want to fill this fourth glass full with water.

What questions to ask:

1. How can the three knives make such a strong support?
2. How are the knife ends held up?
3. What does the weaving of the knives actually accomplish?
4. What other materials could we use instead of the knives?

How to explain it:

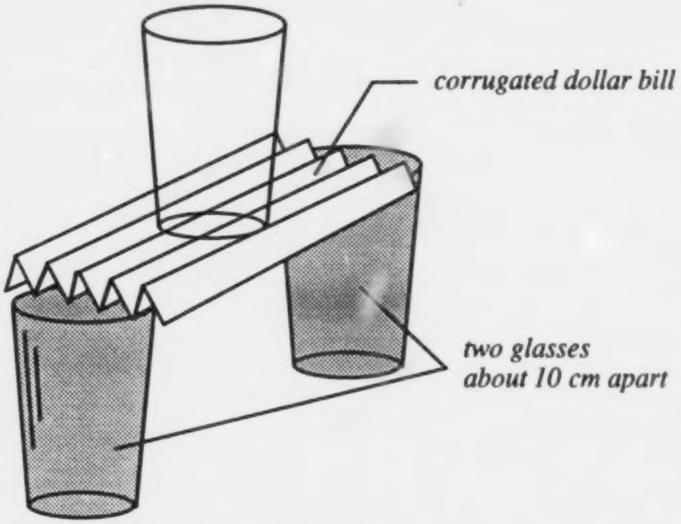
The end point of each of the knives is resting on the middle of the next knife, which the **weaving structure** actually accomplishes. By weaving the knives they act like a solid metal plate, which is certainly strong enough to hold up a considerable amount of weight. The structure is actually just as strong as the knife itself.

Any other stiff material, like forks or spoons, or chop sticks may be used instead of the knives.

3.1.36. THE DOLLAR BILL BRIDGE

What you need: 1. A dollar bill (any denomination or other currency).
2. Three drinking glasses (one empty, the others may be full).

How to set it up:



1. Place two drinking glasses (that may be full or empty) about 4 cm less than the length of the dollar bill apart from each other.
2. Show people the third empty glass and the dollar bill. Ask: "Can you support the third glass at glass-height in between the two glasses?" Anticipated answer: "It s impossible!"
3. Say: "Nothing is impossible!" Proceed to fold the bill in half lengthwise then fold this in half again, and once more in half. Unfold the bill and fold it now in and the next crease out as in pleads of a skirt (in zig-zag pattern when seen from the side). Make sure that the folds are sharply creased (use your nail to press).
4. Spread the pleated bar somewhat out and place it over the two glasses, bridging the two, and carefully place the third glass in the center on top of the dollar bill. Voila! The dollar bill bridge!

What questions to ask:

1. What made the dollar bill so much stronger?
2. Where do we see this similar structure in nature?
3. Can you find similar zig-zag structures (corrugated sheets) that strengthen different materials in our daily life?
4. Would more and smaller corrugations be stronger than fewer and larger corrugations in the dollar bill? Which is better?

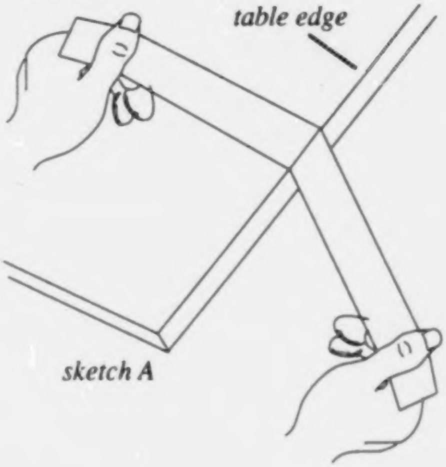
How to explain it:

Providing the dollar bill with the length-wise **corrugations** actually turned the bill into a strong beam across the two drinking glasses. There is an optimum number of corrugations which gives it an optimal strength. The larger the corrugations the less zig-zags we can make from the width of the dollar bill, and the more corrugations the smaller they are and thus the weaker.

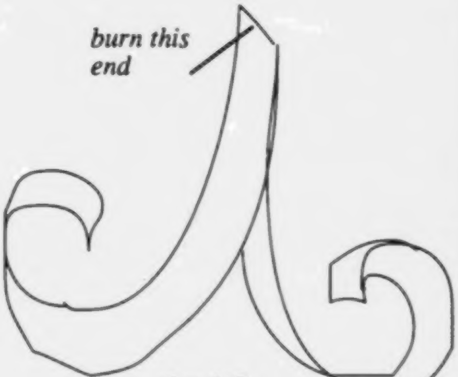
In nature we find similar corrugations in celery stalks and other plant tissues. In our daily life we encounter the zig-zag or corrugated structures in bridges, plastic roofing, cardboard boxes - cardboard consists of two layers of heavy paper with a corrugated layer in between.

3.1.37. HOW LONG CAN YOU HOLD THE BURNING PAPER ?

What you need: 1. A strip of paper (about 30 cm long, 4 cm wide). 2. A sharp edge of the table, and a match.



sketch A



sketch B

How to set it up:

1. Take the ends of the paper strip, one end in each hand, and rub it over a sharp edge of furniture (edge of table or chair). Do this 2 or 3 times (see Sketch A).
2. Notice that the paper strip curls up. Now fold the paper in the center in the opposite direction of the curl (see Sketch B), and hold the two ends together. (You may want to tape the ends together if you like to leave it lying on the table beforehand).
3. Now you are ready to ask a student: "If you hold the strip of paper (at the taped end) vertically, and I burn the top, how long do you think it will take before you have to let go of the paper?" Anticipated answer: "About half a minute".
4. Have a student hold the paper upright and burn the folded end. In about 3 seconds he/she will let go of the paper!

What questions to ask:

1. What did the rubbing of the paper over the sharp edge do to it?
2. What made the student drop the paper so quickly?
3. How can we uncurl a curly strip of paper?
4. What did the burning of the folded end of the strip of paper do?
5. What would happen if we held the paper horizontally and burned it?
6. Would you hold the paper vertically downwards and start burning it from the bottom?

How to explain it:

By rubbing the paper over the sharp edge, we caused the outside of the paper to stretch more, and thus a **tension** in the paper is created. When the paper is burned at the folded end, it separates and the two loose burning ends come curling downwards with lightning speed. Nobody would be holding on to a burning piece of paper if the flame suddenly moves towards the person. The immediate reaction of the person would be to let go of the burning paper.

Straightening out a curling strip of paper can be done by rubbing the outside of the curl over a sharp edge. Another way would be to apply heat to the piece of paper, by ironing for example.

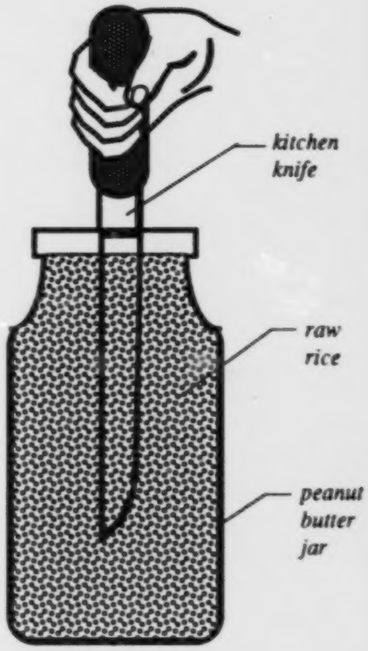
3.1.38. THE STICKY KNIFE

What you need: 1. An empty jar (peanut butter/jam/coffee)
2. A medium-large, wide blade kitchen knife.
3. Raw rice grains (2-3 lbs)

How to set it up:

1. Fill the jar almost completely full with the rice grains.- mark the level of the grains on the side of the jar.
2. Take the knife by the handle and plunge the blade vertically into the rice grains. Show to the students that they are just loose grains, and that the knife can easily be lifted.
3. Plunge the knife several times into the jar of rice (4-5 times or sometimes even more) and slowly and steadily lift the knife vertically - the whole jar will lift with it!

   If the jar of rice is used for the first time, you may need to plunge the knife a few more times into the jar before it will be lifted by the knife.
4. Notice the level of the grains after the knife has been plunged several times into the rice grains. How did it change?



What questions to ask:

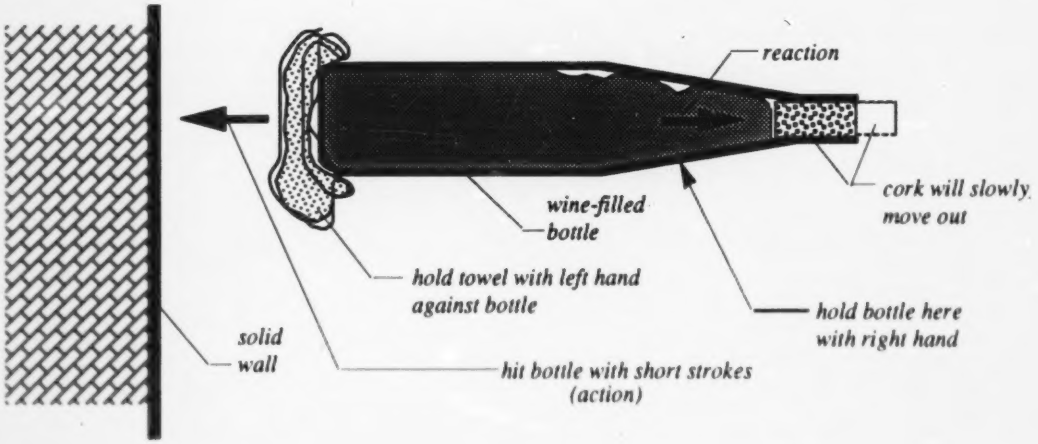
1. How did the level of the rice grains in the jar change when we compare the first level with that after the knife has been plunged into it several times?
2. Did the resistance of plunging the knife into the grains change with the number of trials? How did it change? Why?
3. Why do we need to plunge the knife into the rice several times before it sticks?
4. What made the knife stick to the grains or the grains stick to the knife?
5. Will the same "sticking" occur in a jar with a wider opening than the bottom?
6. Where do the forces occur between the knife and the jar?
7. Can this phenomena occur by using other types of grain? Other knives?

How to explain it:

By plunging the knife for the first or second time into the rice grains, not much rearranging occurred between the grains, and that is why it is still easy to slide out the knife. After plunging it several more times into the grains, they get **packed** tighter. Because the knife is narrower and usually thinner towards the end, at one point the plunging of the knife pushes the packed grains towards the sides of the jar, and the grains push back towards the knife. The jar of grains act like one piece, just like a piece of wood, and the whole jar lifts with the knife. The **force** that the knife exert is **against the sides** and narrower part of the jar. This lifting cannot be done in jars with wider mouths.

3.1.39. HOW CAN WE GET THE CORK OUT? (I)

What you need: 1. An unopened bottle of wine (corked).
2. A cloth napkin or towel. 3. A solid wall (concrete or steel beam).


reaction
cork will slowly move out
wine-filled bottle
hold towel with left hand against bottle
hold bottle here with right hand
solid wall
hit bottle with short strokes (action)

How to do it:
1. Wrap the towel around the bottom of the wine bottle, making sure that the towel provides a thick cushion on the bottom of the bottle.
2. Hold the bottle by the neck with your right hand, using your left hand to keep the towel against the bottom of the bottle, and hit the bottle against the solid wall with successive small thumps (see sketch above).
3. Observe the cork coming out of the bottle very gradually with every 3-4 hits!

What questions to ask:
1. What function does the cloth napkin or towel have?
2. What can be used instead of the towel?
3. What made the cork move slowly out of the bottle?
4. Would this happen without wine in the bottle or with a half-filled bottle?
5. Will this procedure work better/easier with a wider or a narrower bottle (with the same mouth opening)?
6. What characteristic of the bottle is most critical?
7. Will a smaller (narrower) cork be easier or harder to take out of the bottle?

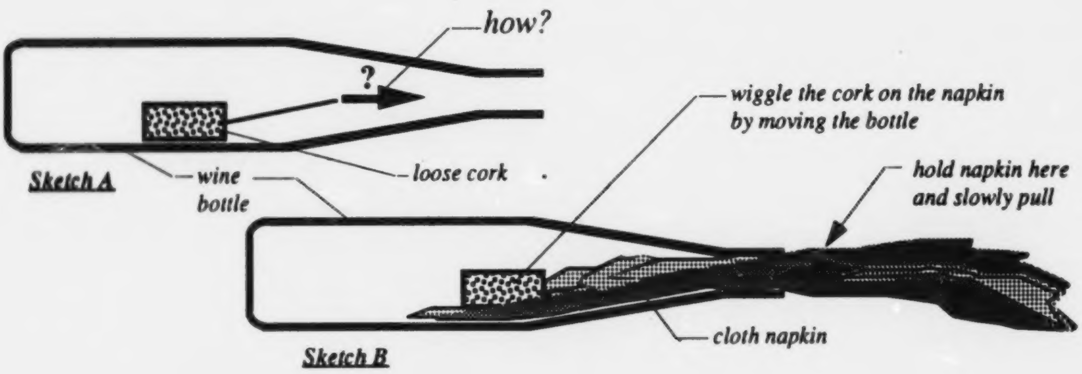
How to explain it:

For every action (force) against the wall with the bottom of the bottle, **there is an equal and opposite reaction** on the fluid (wine), which is transferred to the cork in the bottle mouth. The force exerted by the bottom against the wall was spread over the area of the bottom. The reaction, which is equal to this force, was spread over a much smaller area of the bottle opening (cork). This multiplied the pressure on the cork with a ratio of bottom area : neck opening area. The larger the bottom of the bottle or the smaller (narrower) the cork, the easier to open the cork using this method.

The function of the cloth is to soften the impact of the glass bottle against the solid wall - in other words, to prevent shattering of the bottle. A wall that has a little of give to it, will not work for this demonstration (for example: regular gyp-rock walls). A concrete wall or steel beam/post is working best to get positive results!

3.1.40. HOW CAN WE GET THE CORK OUT ? (II)

What you need: 1. An empty wine bottle with its cork. 2. A cloth napkin.


how?
?
loose cork
wine bottle
Sketch A
wiggle the cork on the napkin by moving the bottle
hold napkin here and slowly pull
cloth napkin
Sketch B

How to do it:

1. If the cork is loose outside the bottle, take it and push it in the bottle: completely inside the bottle.
2. Ask the students: "How can we take the cork out of the bottle, such that we can reuse the bottle and the cork?"
3. Take the napkin's corner, make a narrow chute out of it and push it as deep as possible inside the bottle.
4. Now wiggle the cork on top of the napkin inside the bottle.
5. Pull the napkin slowly out, making sure that the cork comes with it, until it gets tight (the cork is now pinched in the bottle neck with the napkin on one side of the cork).
6. Once the napkin is stuck between the cork and the bottle in the bottle neck, pull the napkin with a sharp yank the cork will shoot out!

What questions to ask:

1. Why did the napkin not come out by itself?
2. What other ways would there be to get the cork out?
3. What other materials can we use instead of the cloth?
4. Is it easier to rub the cork against a glass surface or against the cloth surface?
5. Would an oily or wet cloth make it harder or easier to get the cork out? Why? Why not?

How to explain it:

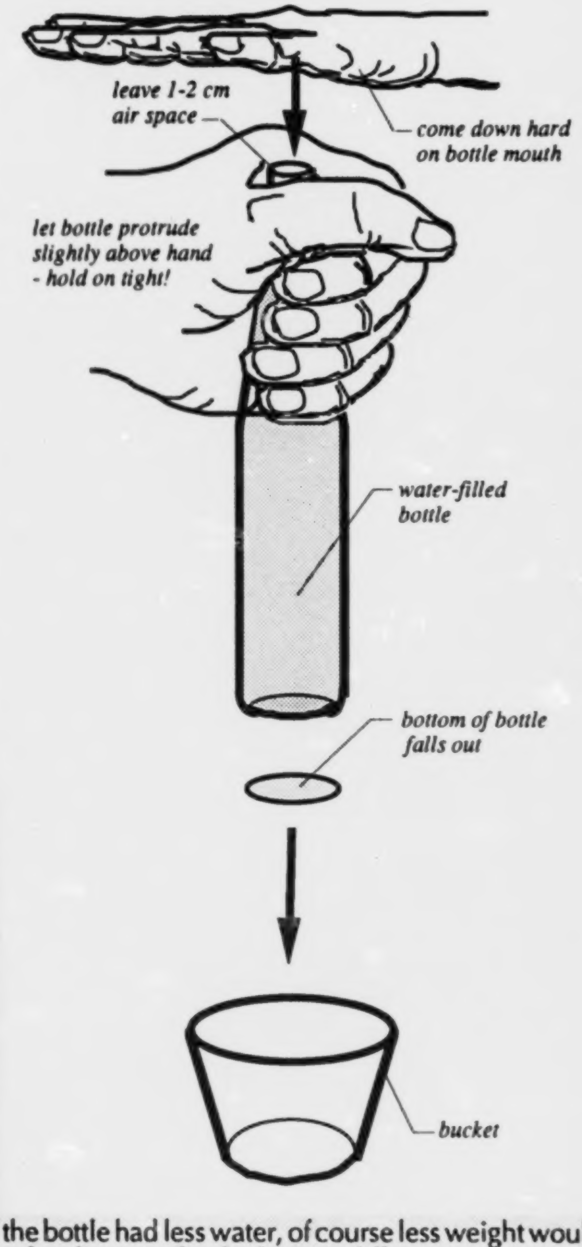
This demonstration is particularly suited to get the students to use their **imagination,** because **"imagination is more important than all the facts in the world",** said Einstein. Ask for suggestions as how to get the cork out of the bottle, without breaking the bottle or the cork. After students give up, take the cloth napkin and demonstrate. The cork comes toward the bottle neck when the cloth is slowly pulled out. The pulling of the cloth gets harder now, because the bottle neck is tapered. When the napkin is yanked out of the bottle, the cork comes with it, because the **friction** between cork and napkin is much greater than that between cork and glass (bottle). The rougher the cloth, the easier to get the cork to come with it. Oily or wet cloths will not be as effective to get the cork out.

If it is a new bottle of wine, and we want to take the cork out without a cork screw, then we can do it by hitting the bottom of the bottle against a solid wall (see preceding event: "HOW CAN WE GET THE CORK OUT (I)")

3.1.41. THE WATER HAMMER

What you need: 1. A glass soda-pop bottle.
2. A rubber mallet (not essential).
3. A bucket.

How to do it:
1. Fill the bottle almost full with water - leave about one inch of space on the top.
2. Hold the bottle vertically by the neck close to the mouth with one hand and strike the opening with the mallet or palm of the other hand. Do this while holding the bottle over the bucket.
3. The bottom of the bottle will fall out! If this does not succeed, try again!


leave 1-2 cm air space
come down hard on bottle mouth
let bottle protrude slightly above hand - hold on tight!
water-filled bottle
bottom of bottle falls out
bucket

What questions to ask:
1. What is the purpose of the air space above the water?
2. What does the water do when the bottle is hit?
3. Would the weight of the water affect this event?
4. Would this work with other liquids? Which?
5. Why does only the bottom of the bottle fall out?
6. Would this work if the bottle was only half or three quarters, or completely full?

How to explain it:

The blow on top of the bottle moves the bottle suddenly downwards. Since there is a space above the water, the water moves up (relative to the bottle) - actually the water tended to stay at rest - **NEWTON'S LAW - FIRST PART : Objects at rest tend to stay at rest,** and this creates a vacuum immediately above the bottom of the bottle (on the inside) for a very short moment. Then suddenly the water comes back down with such a force that the water pressure pushes the bottom out.

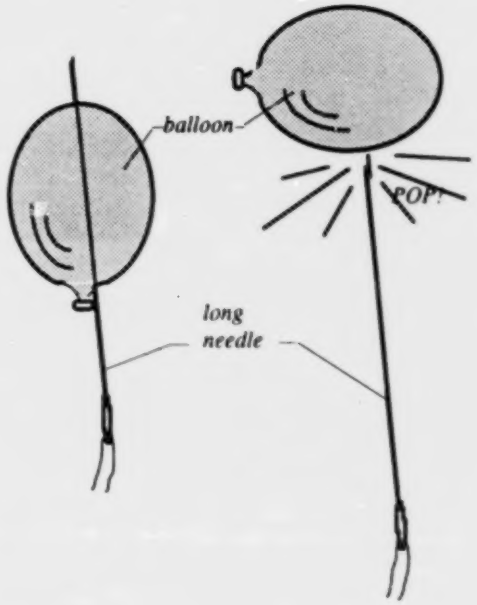
If the bottle was totally full with water, there is no space for the water to move up in the bottle, no vacuum would be created, and no sudden pressure would be formed. If the bottle had less water, of course less weight would be pushing on the bottom and it will thus be harder to make the bottom fall out.

3.1.42. PUSH A NEEDLE THROUGH A BALLOON ?

What you need: 1. A large round uninflated balloon.
2. A long (about 2 ft) needle (with or without an eye)
3. A few drops of glycerin.

How to do it:

1. Inflate the balloon by blowing some air in it, but make sure that the end of the balloon stays somewhat thick (do not inflate it completely!) and put a knot in it.
2. Dip a piece of cloth or tissue paper in the glycerin and moisten the long needle from point to eye with the glycerin by wiping it with the tissue.
3. Now push the needle point through the balloon close by the knot and through the thick part of the balloon end.
4. If the needle has an eye, thread it and pull the needle completely out of the balloon from the point side, but leave the thread in it.
5. Now take the needle completely off the thread (or off the balloon if it has no eye), hold the balloon in your left hand and puncture it with the needle point - touch the thin part - POOF!



What questions to ask:

1. Why didn't the balloon burst when the needle was pushed through the first time?
2. What purpose did the glycerin have?
3. What other substance may be used instead of glycerin?
4. Would this demonstration be easier or harder to do with small size balloons? Why?
5. At which spots did the needle go through the balloon?
6. At which spot did the needle point touch the balloon to make it burst?

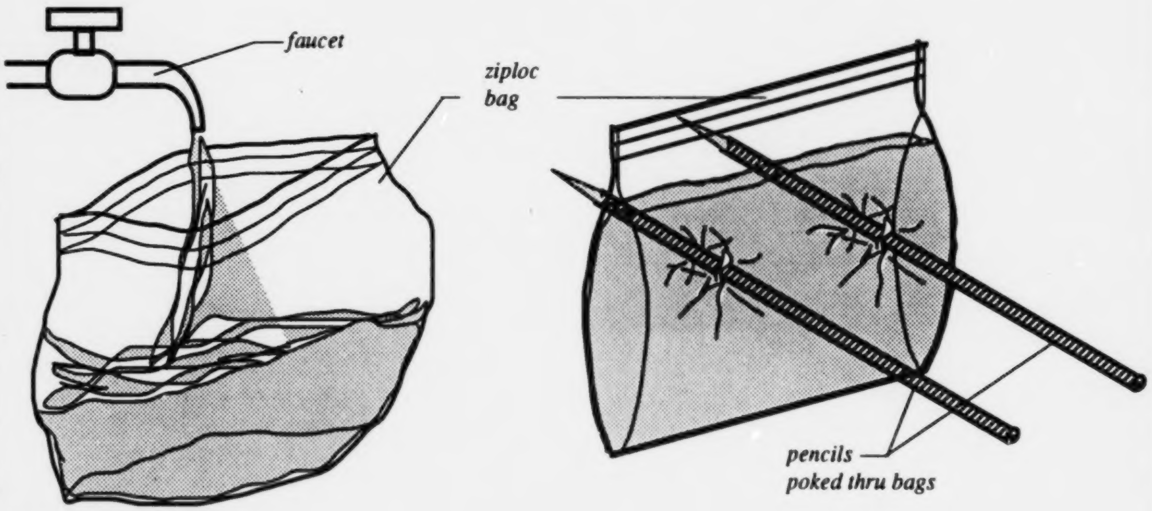
How to explain it:

This demonstration is easier to do with large balloons as compared to smaller ones, because the large ones are usually thicker, and thus stronger. (Latex balloons are the best for this purpose). The balloon does not burst if the needle is pushed through the thicker parts, that is why it is absolutely essential not to completely inflate the balloon. Only when the balloon is completely inflated to its maximum will there be no thick parts left in it. The thicker parts of the balloon have enough rubber, such that **shearing** will not occur. When the time comes to show that the needle has indeed a sharp point, we touch the thin part of the balloon, and POOF! - the **shearing force** just tears the balloon to bits.

When we approach a balloon with a sharp object, we usually cover our ears, anticipating a loud POP from the bursting of the balloon. Why is it that the bursting of a balloon is always accompanied with a loud popping sound? This happens because there is compressed air in the balloon and when this air is suddenly released - by the bursting of the balloon - a strong wave is created in the air, which reaches our ear drum and makes the ear drum vibrate.

3.1.43. THE WATER-TIGHT ZIPLOCK BAG

What you need: 1. A small, plastic ziplock bag. 2. A couple of sharp pencils.



How to do it:

1. Fill the plastic ziplock bag almost full with water and close the zip tightly.
2. Show students that you can turn the bag upside down or lie it on the table without spilling the water out . Tell them that the bag is indeed so water-tight that we even can puncture it with a pencil without spilling the water.
3. Hold the ziplock bag in your left hand and push the first pencil somewhat on the side through the bag with one straight stroke, making sure that you do not move the pencil sideways!
4. Once the first pencil is completely through the bag, push the second pencil through with the same swift straight stroke (like throwing a spear at a fish).
   Practice this jabbing action with the pencil several times over the sink or a bucket!

What questions to ask:

1. Why does the pencil have to be pushed through the bag with a straight stroke?
2. How can we stop the leak, once we made a hole in the bag with the pencil?
3. What other objects can we use to replace the pencil?
4. When the pencil is jabbed straight through the bag, why does the water not leak out?
5. Could we use a drinking straw to puncture the bag? When holding the straw with a finger at the end, would there be water in the straw after puncturing the bag of water?

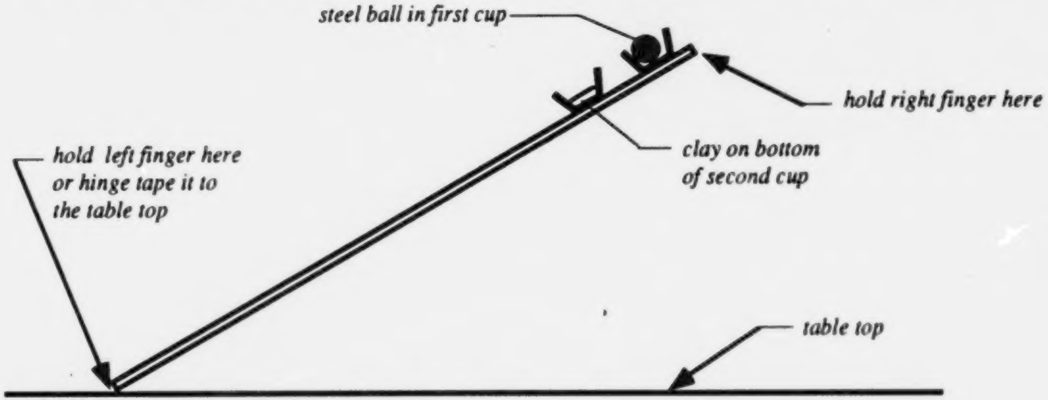
How to explain it:

When the plastic bag of water is punctured with the pencil with a straight stroke, no water will be spilled out of the bag This is because plastic, which is polyethylene, is **stretchable.** This means that the hole made by the pencil is actually smaller than the diameter of the pencil. The plastic actually folds around the pencil and the **water pressure** presses the plastic against the pencil so that no water can leak out of the bag. If a small sideways force is applied to the pencil, the plastic tears, and a larger hole is made in the bag, resulting in a water leak. In order to stop a leak, once a hole is made in the bag, a larger diameter pencil or dowel (or any other cylindrical object) may be pushed into the hole.

When a straw is used to puncture the water-filled bag, it is essential to hold a finger against the end of the straw. When this straw is jabbed through the bag, at the moment that it hits the bag, air is trapped inside the straw, and it becomes rigid and acts like a solid rod. This means that after the straw went through the whole bag, no water is actually trapped inside the straw.

3.1.44. THE MYSTERIOUSLY MOVING BALL

What you need: 1. A wooden stick (1"x 1/4" x3') about the size of a meter stick.
2. Two small plastic or paper cups.
3. Thumb tacks & Masking tape.
4. A blob of moulding clay.
5. A steel or plastic ball (3/4" diameter)


steel ball in first cup
hold right finger here
hold left finger here or hinge tape it to the table top
clay on bottom of second cup
table top

How to do it:

1. Attach the two cups at one end of the stick about 2" (5 cm) from each other with the thumb tacks and the masking tape. (see Sketch).
2. Tape the other end of the stick to the table top so that it hinges around the end (see Sketch).
3. Place a small blob of clay in the second cup (from the end) and spread it out on the bottom.
4. Place the ball in the end cup and lift the stick at the cup end about 2 ft (50 cm) (see Sketch).
5. Remove your finger that held the stick up with a sudden movement away from the stick end, in other words: let the stick end suddenly fall!
6. Observe the ball: it moved into the second cup! (If it does not fall in the second cup, vary the initial height of the stick and practice letting go of the stick end)

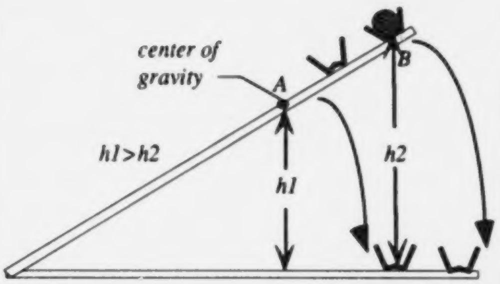
What questions to ask:

1. Did the ball experience free fall?
2. What point of the stick actually experienced free fall?
3. Was the very end of the stick falling slower or faster then a free fall?
4. How could the ball actually jump out of the first cup?
5. How far can the second cup be placed and yet still catch the falling ball?
6. What would be the optimum height of the stick end, so that the ball would move easily?
7. How can we test which point of the stick is actually experiencing free fall?
8. Will the ball always jump out of the cup no matter where the cup is placed on the stick?

How to explain it:

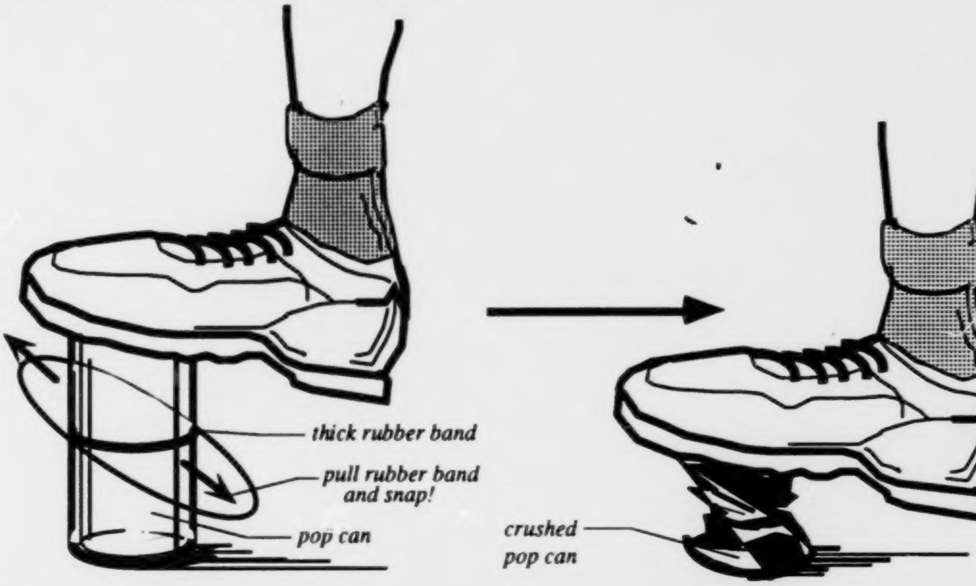
The **center of gravity** of the lath with the cups attached is about 2/3rd away from the hinged end. This point falls at the same rate as the steel ball. As point A (center of gravity) is not as high above the table as point B (h2>h1) point B has to fall faster than a regular **free fall.** Thus, the right-hand end of the lath indeed falls faster than the steel ball, and as the ball falls in a straight path, it ends up in the second cup.

This means then that when a hinged lath or stick **falls freely**, the end of the stick which is not higned, always falls faster than a free fall (assuming that the hinged end is not moving).



3.1.45. CRUSH THE CAN WITH A RUBBER BAND ?

What you need: 1. An empty soda pop can. 2. A thick rubber band.



How to do it:

1. Place the rubber band around the pop can in the center of the height.
2. Put the can on the floor near a table or chair (to hold on to), and have a student of about 100 lbs stand on the can with one foot, while holding on to the table or chair.
3. Now stand in front of the student face to face, squat down, pull the rubber band on both sides of the pop can and snap both sides at the same time! **CRUSH!**

What questions to ask:

1. What was holding up the student's weight?
2. What would happen if the weight of the student standing on the can is too heavy?
3. What is the maximum weight that the pop can is able to hold before crushing? How can we find out?
4. What would happen if only one side of the rubber band was snapped?
5. What else could we do instead of using a rubber band?
6. In which direction does the rubber band exerts its force?
7. Can you name some examples where this particular principle is applied in daily life?

How to explain it:

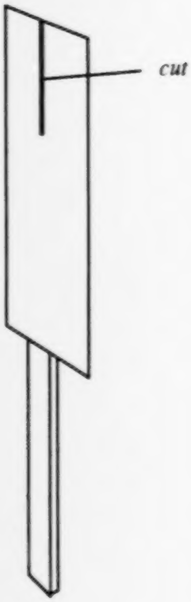
Depending on the soda pop can, the maximum weight it can support is between 100 and 150 lbs (or between 60 and 90 Kg). When we step on this pop can, our weight or the force is vertically downward. When the rubber band is snapped on both sides, it exerts **a force perpendicular** to the weight, and suddenly the can is not able to hold the weight, and the can crushes.

Instead of the rubber band, a ruler can be used. Just a quick hit on the side of the can will make it crushing down. It is better to use two rulers and hit the can on both sides. If we use only one ruler or let the rubber band snap only on one side, the can may get crushed on one side more so than on the other, and the student may fall to one side.

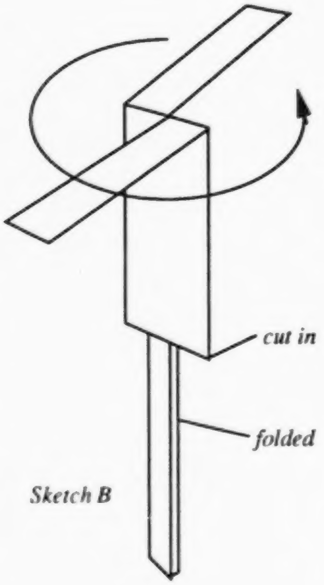
We see this principle applied in daily life, when we see old tall buildings being demolished. The dynamite is placed near the bottom of the building so that the weight of the building itself will destroy it. It is very important to let the blasts go off exactly at the same time at all sides of the building, otherwise it may come down sideways and destroy other surrounding buildings.

3.1.46. THE CONFUSED TWIRLING PAPER

What you need: 1. A strip of paper (about 15 cm long, 5 cm wide). 2. A pair of small scissors.



Sketch A



Sketch B

How to do it:

1. Take the paper strip and cut about 5 cm into the center of the strip and fold the two parts to opposite sides of the strip (see Sketch A).
2. At about 5 cm from the other end of the strip, cut crosswise one third into the width of the strip and fold the two parts on top of each other, making the bottom part thicker (see Sketch A).
3. Take the paper piece in the middle and drop it to the floor from standing height. Which way does the paper piece rotate? (See Sketch B)
4. Now fold the two "wings" to the opposite side. Drop the paper piece again from standing height to the floor. Which direction does it rotate?

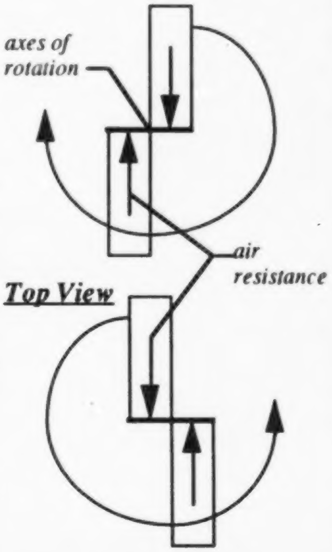
What questions to ask:

1. What makes the paper piece rotate when dropped to the floor?
2. What are the forces working on the paper piece?
3. What direction did it rotate the first time? And the second time?
4. What made the rotation change direction?
5. Can you find examples in nature making use of this principle?

How to explain it:

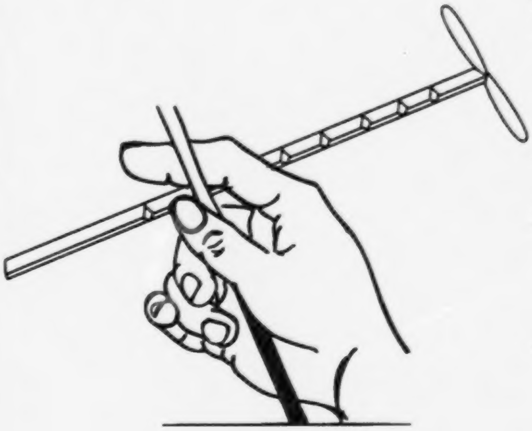
The forces working on the paper piece when dropped to the floor are caused by **air friction**. When looking at the piece from above (obliquely, like in Sketch B above), and the right wing is folded away from you and the left towards you, dropping it will make it rotate clockwise. When the "wings" are folded in the opposite way, the paper piece rotates counter clockwise. When we look at the forces working on the paper we note a **torque** working in both cases (see Sketch on right).

Many seeds of different fruits in nature are equipped with "wings" which will promote the propagation of the seeds when released from the ripe dry fruit.



3.1.47. THE YIP-YIP STICK

What you need: 1. Two wooden dowels (one somewhat thinner than the other). or two small pine sticks (about I x I x I5 cm). 2. A coffee stirrer and a small nail.



How to do it:

1. Make small notches on one edge of the pine stick about 1 cm apart from each other. The notches should be about 3 mm deep and about 2 mm wide.
2. Cut a 6 cm piece off from the coffee stirrer and make the same rounding edge on the cut end.
3. Nail the middle of this piece of stirrer to the top end of the pine stick, and wiggle it so that it will turn loosely around the nail (the nail should be hammered in only half way).
4. Hold the smaller stick in your right hand (if you are right handed) with your index finger pointing out (see Sketch) and hold the notched stick in your left hand.
5. Rub the notched stick with the smaller stick over the notches and let your thumb slide on the right side of the notched stick (stirrer will rotate counter-clockwise as seen from the performer's viewpoint).
6. Tell the audience that the stirrer (rotor) will turn the opposite way when you say "Yip-yip". Say "Yip-yip" and keep rubbing the notched stick but this time let your index finger slide against the notched stick. Observe the rotor rotate in a clockwise direction!

What questions to ask:

1. What made the rotor turn?
2. What caused it to turn one way and what caused it to turn in reverse?
3. Did the saying of "Yip-yip" have anything to do with turning it in reverse?
4. Does the distance between the notches have an influence on the rotation?
5. Does the speed of the rubbing have anything to do with it?
6. Would rubbing the notched stick on one side, then turning it to the other side, have anything to do with it?
7. What would happen if you held the smaller stick another way?

How to explain it:

The rubbing of the smaller stick against the notched stick with the rotor on, produces **vibrations**. When the thumb is held against the notched stick while rubbing, the **oscillations** take the form of an ellipse causing the stick to vibrate in a counter-clockwise direction, and thus the rotor rotates that way too.

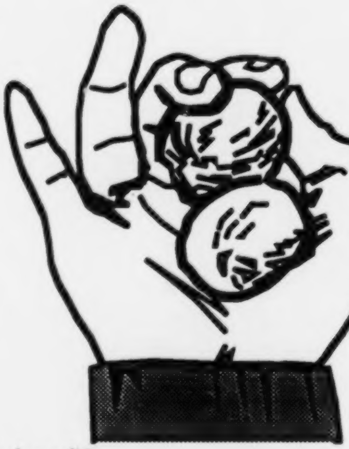
When the index finger is held against the notched stick, the oscillations are slanted in a clockwise direction. This changing of rotational direction can also be achieved by turning the notched stick slightly to the left or to the right, in other words by rubbing the notches on the left side as compared to rubbing it on the right side.

3.1.48. CRACK A NUT

What you need: 1. Two walnuts.

How to do it:

1. Hold one walnut in your hand and try to crack it open without using any utensils.
   You will find that it is almost impossible to do!
2. Hold both walnuts in the same hand (see Sketch) and use the same force to crack the nuts open: one of the nuts cracks!



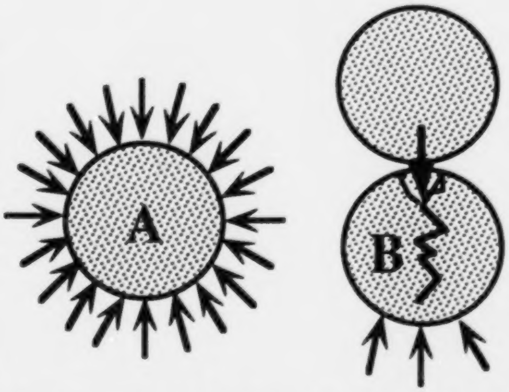
What questions to ask:

1. Why is it so difficult to crack the nut, if we have only one in the hand?
2. Did your hand press harder when you had two nuts in the hand?
3. When you had only one nut in the hand, which surface of the nut was in contact with the hand?
4. With the two nuts in the hand, was the contact surface between the two nuts smaller or larger compared to the contact surface between hand and nut (with one nut in the hand)?
5. Why was the force applied on the nut not great enough to crack it with one nut in the hand?
6. Where is this principle of spreading the force over a larger surface area to reduce it being used in other situations in daily life?

How to explain it:

When only one nut was held in the hand, the force of the closing hand was spread over almost all of the nut surface (see Sketch Nut A). With two nuts in the hand, the **contact surface** between the two nuts is very small.

The force that was first spread over the upper half of the nut is now concentrated onone spot (see Sketch Nut B). Although the hand was actually exerting the same force with the one nut or with two nuts in the hand, the **pressure = force per square inch of surface area** is much greater on nut B (with two nuts), therefore it cracks open!



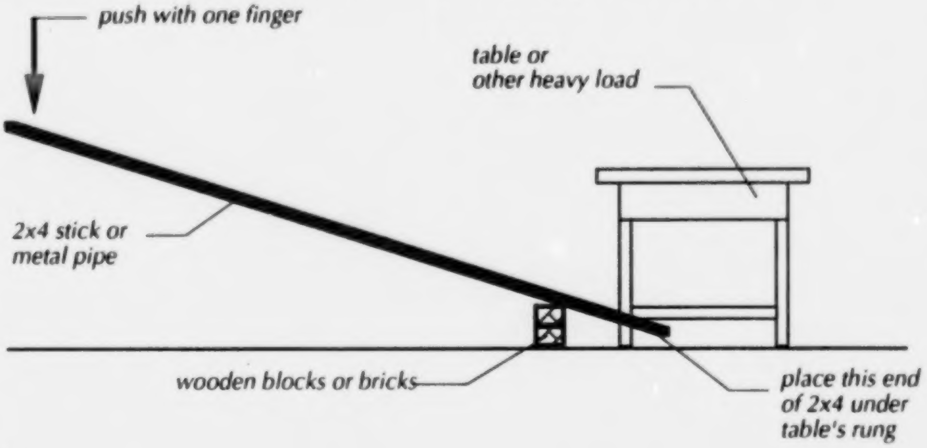
This same principle of reducing the **force** by **spreading it over a larger surface** is applied when helping someone who has fallen through thin ice in the winter. In order not to fall through the thin ice and yet come close to the drowning person, one has to lie down on the ice, spread arms and legs, and pull the person out of the freezing water.

Another example in daily life is in **carpentry**, when wanting to move a nice finished piece of wood a fraction of an inch with a hammer and we do not want to mar its surface, we take a piece of wood that has a larger surface than the hammer head, place it on the finished surface and hit the small piece of wood. This way no damage is done to the nice finished surface, because the hammer blows are not concentrated in one small spot, but spread over a much larger area.

You might have seen the trick where a person lies on a bed of nails, and a block of concrete placed on his body is smashed in half with a mall (large hammer) without harming the person. This is the same principle applied, where the person's weight is distributed over the whole body surface (the nail points are about an inch apart from each other), and thus the force of the hammer is spread over the large concrete block surface on one side and the body surface on the other side.

3.1.49. TILT A HEAVY LOAD WITH ONE FINGER

What you need: 1. A long wooden stick (shovel handle) or an iron water pipe (3-4 m).
2. Two or three small wooden blocks. 3. A heavy piece of furniture.


push with one finger
table or other heavy load
2x4 stick or metal pipe
wooden blocks or bricks
place this end of 2x4 under table's rung

How to do it:

1. Have students try to lift one side of the heavy piece of furniture to give them an idea of its weight.
2. Place the two or three wooden blocks close to the side of the table to be tilted, place the end of the long stick under the table rung and use the blocks as a fulcrum for the lever (see Sketch).
3. Now push the long end of the stick with one finger down (as a heavy load, a desk or table, or a chair with a student sitting on it, may be used; make sure that a rung or horizontal bar is present, close to the bottom of the load to be lifted, to hook the lever on).

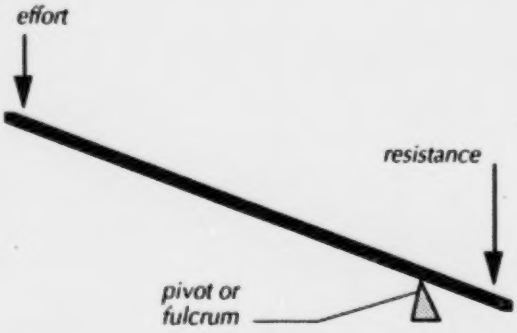
What to ask:

1. What type or class of lever are we dealing with?
2. What functions as the resistance in this case?
3. What were the effort and the fulcrum in this lever?
4. What other examples can you name that are based on this class lever?

How to explain it:

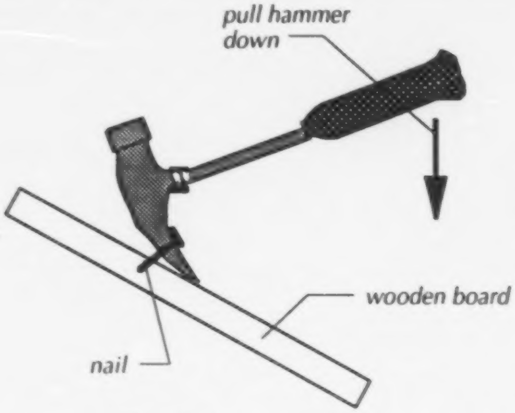
This **lever of the first class** has the **pivot** or **fulcrum** in between the **effort** and the **resistance.** The latter one being the heavy load (table, desk, or chair with someone seated on it) and the effort being the finger pushing on the long end of the lever, and the blocks of wood serving as the **pivot** or fulcrum.

Other examples applying the first class lever are: a pair of pliers, a pair of scissors, wire and chain cutters, most car jacks, teeter totters, crowbars, etc.

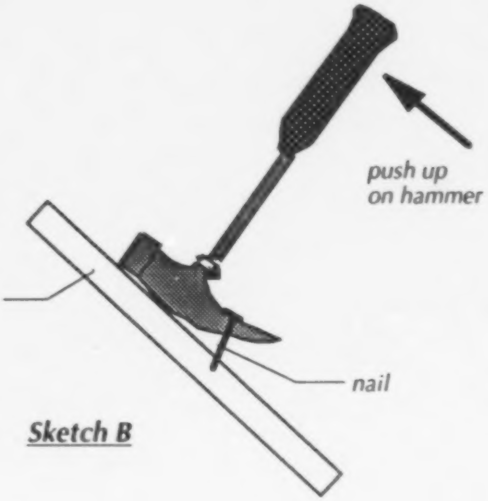

effort
resistance
pivot or fulcrum

3.1.50. IS THE HAMMER A LEVER ?

What you need: 1. A hammer (which can be used to pull nails out).
2. A wooden board and small common nails.



Sketch A



Sketch B

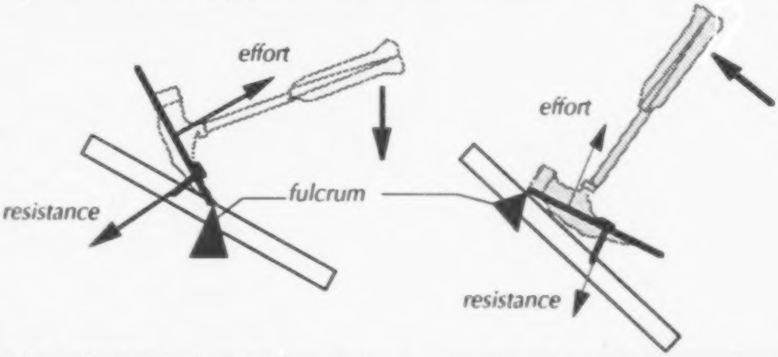
How to do it:

1. Hammer a couple of nails into the wooden board (half way) and pull one nail out by pushing down on the hammer (see Sketch A).
2. Pull the other nail out by pulling up on the hammer (see Sketch B).
3. Ask students the questions listed.

What to ask:

1. Which of the two methods of taking out the nails was an application of the second class lever?
2. What class lever was the other method applying?
3. Where is the fulcrum, effort and resistance located in method A? Where are these in method B?
4. What other examples can you name that apply the second class lever?

How to explain it:

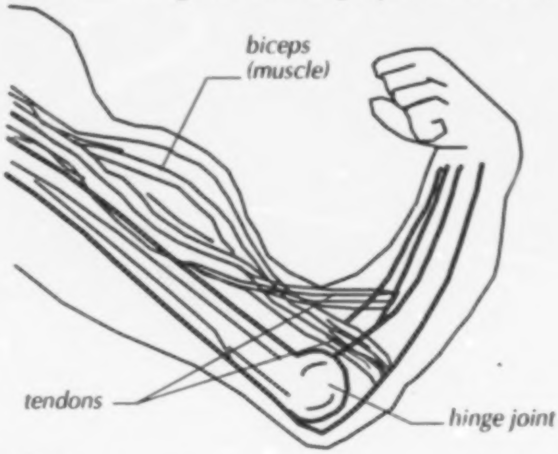


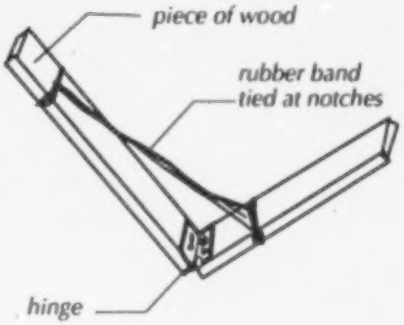
The best way to clarify where the forces are at work with the hammer pulling the nail, is to draw a sketch of both methods and the relationships and location of the **forces** and **fulcrum**.

Method A is applying the **second class** and method B the **third class** lever. Other examples of second class lever applications are: the wheelbarrow, crowbar, nutcrackers, paper cutters, two-hole punchers.

3.1.51. THE THIRD CLASS BICEPS

What you need: 1. Two pieces of wood (or two rulers).
2. A small hinge (or masking tape), & thick rubber band.





How to do it:

1. Attach the two pieces of wood together by means of the hinge (or tape the two rulers loosely together).
2. Cut grooves for the rubber band close to the free end of one arm and close to the hinged end of the other arm.
3. Tie the rubber band around each arm where the grooves are. You are now ready to show the biceps action.

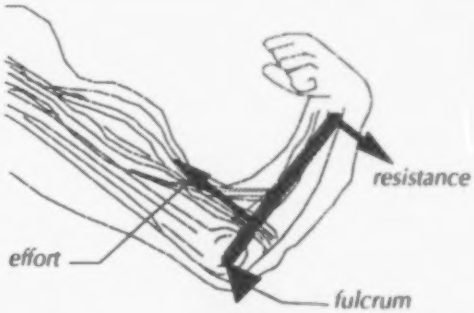
What to ask:

1. What class lever is the movement of the lower arm based on?
2. What does the rubber band simulate?
3. Locate the fulcrum, effort, and resistance in this arm lever.
4. Are other muscles in our body and the movement of the body parts based on the same class of levers?
5. What other examples can you name that are applying the third class lever in our daily life?

How to explain it:

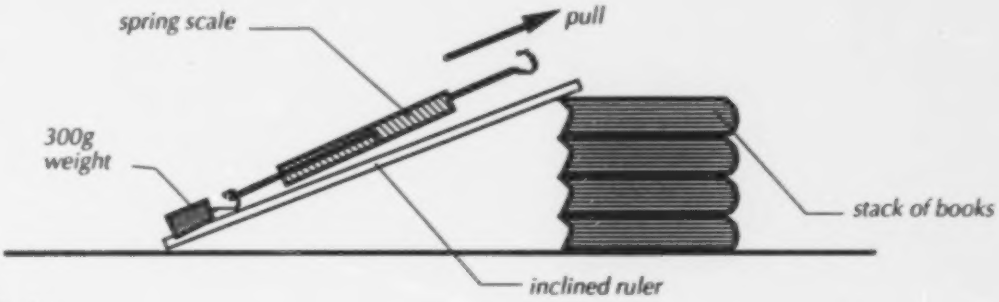
The biceps' action is the **effort** in a third class lever when moving the lower arm upwards. This is illustrated by the rubber band when it is contracting. The hinge is the joint or **fulcrum** between the lower and upper arm, and the **resistance** is the weight of the arm alone or any additional weight that the arm is lifting (see sketch on the right).

Other third class levers in our daily life are: a pair of tweezers, ice tongs, moving a hockey stick, using a shovel, broom, or rake, etc.



3.1.52. WHICH ONE IS HEAVIER ?

What you need: 1. A 200 g and a 300 g weight. 2. A spring scale (500 g maximum).
3. A 30 cm plastic ruler & a stack of books.



How to do it:

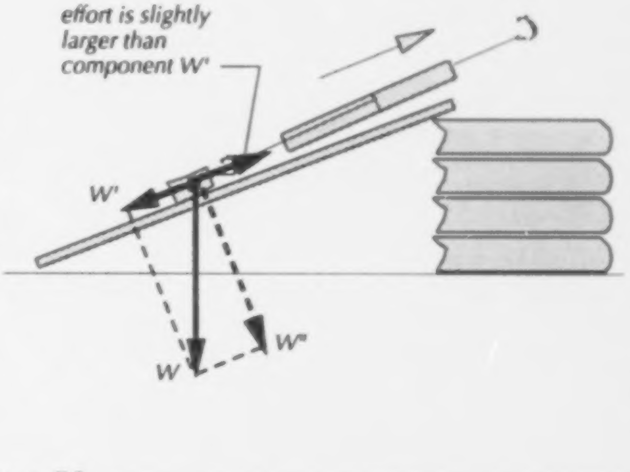
1. Place three or four textbooks on top of each other.
2. Place the two weights next to the stack of books and tell students that your task is to move the weights up on top of the stack.
3. Ask students: "Which one will take more effort to move?"
Place the ruler on an incline (one end on top of the books and the other end on the table), and pull the 300 g weight over the ruler up on the stack of books with the spring scale (read the effort off this scale while moving the load).

What to ask:

1. How much effort did it take to move the 200 g weight straight up?
2. How much effort did it take to move the 300 g weight over the incline on top of the stack?
3. Why was the effort much less than 300 g on the incline?
4. How are the force components working on the incline?
5. What are other applications on the inclined plane?

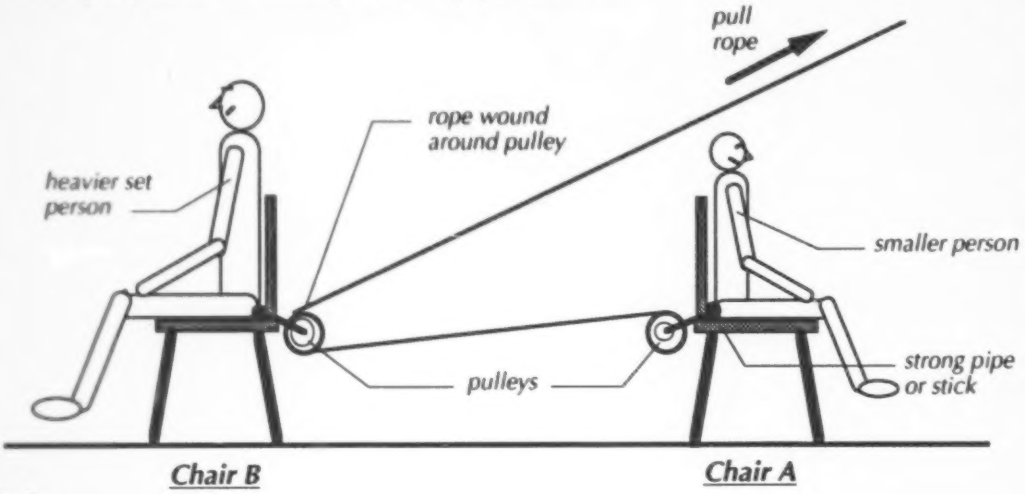
How to explain it:

It takes much less effort than the full weight to move the 300 g mass over the inclined ruler, as the incline component force (W') is much smaller. The less steep the slope of the incline, the smaller the effort. The weight on the incline (W) may be decomposed into a component perpendicular to the incline (W") and one along the incline (W'). The effort would be slightly larger than W' (to overcome friction).
Other applications are: the screw, the wedge, axe, chisel, etc.



3.1.53. WHICH ONE WILL BE MOVED ?

What you need: 1. Two clothesline pulleys. 2. Two straight-back chairs.
3. A sturdy rope and two strong sticks or pipes (50 cm).



How to do it:

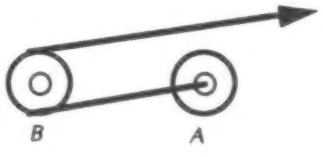
1. Attach each pulley to the center of each of the rods or pipes with a short piece of rope, and slip the rod between the seat and back of each chair, so that it catches on the frame when the pulley is pulled backwards.
2. Tie the end of a long rope to the other hanger of one pulley (see sketch Chair A), and thread the other end of the rope around the pulley of Chair B, and hold the end of the rope on the side of Chair A.
3. Have a tiny built student sit on Chair A and a heavy set student on Chair B, and ask: "Which of the two will be moved when I pull the rope?" (anticipated answer: A). Pull and observe Chair B move! Chair A does not budge at all!

What to ask:

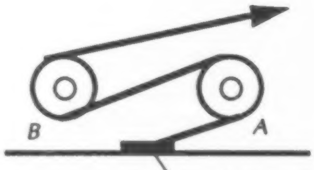
1. Which of the two students is heavier?
2. Why did Chair B, the heavier one, move and not Chair A?
3. Which of the chairs would move if the students were of equal weight?
4. Which one would move if the rope were also wound around pulley A, and the rope end was attached to the floor?

How to explain it:

There is only one rope pulling at Chair A and two ropes pulling at Chair B. **The force or tension in each of the ropes is equal** and thus the force pulling at Chair B is twice as large as that at Chair A. This is why even the heavier student sitting on Chair B is moving. If the rope were also wound around pulley A (in other words, if pulley A was also a working pulley), Chair A would be moved (with the lighter student—see Sketch B on the right).



Sketch A



Sketch B

Modern Communication *has to be:*

R ELAXED

I NFORMAL

P TO THE POINT

E NTERTAINING

THE EGG AND THE MILK BOTTLE

It is fun to see a large egg like that to slip down the narrow bottle neck !

How can you get the egg back out ?

CHAPTER 2

WHAT DO WE LEARN WHEN DEALING WITH SPACE SCIENCE ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts of this chapter, the students should be able to:

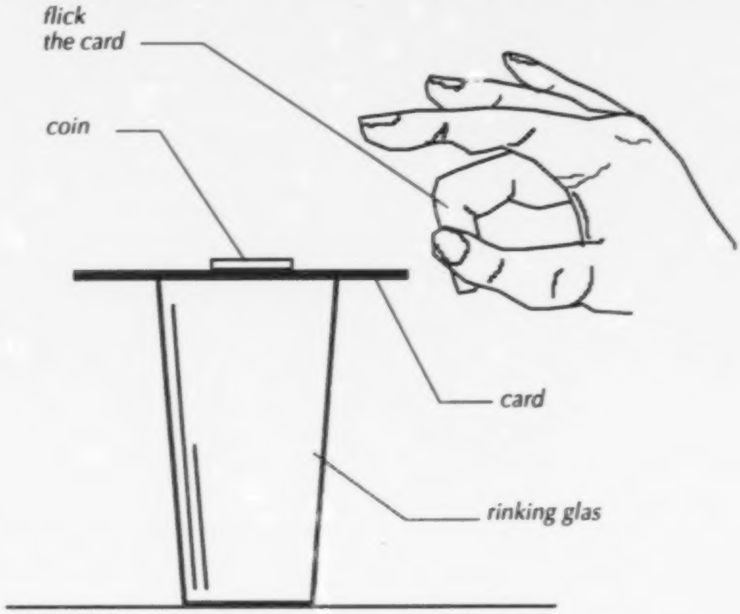
a. Recognize the correct explanation of an observed event based on each of the sub-concepts;
b. Explain in their own words which of the sub-concepts is determining the course of an event;
c. Distinguish true from false statements concerning each one of the sub-concepts;
d. Identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

— Inertia is the tendency of still objects to stay still or at rest.
— The larger the mass of an object, the more inert it is.
— Newton's First Law: a. An object at rest tends to stay at rest.
b. An object in motion tends to stay in a linear motion.
— Newton's Second Law: The acceleration of a moving object is directly proportional to the force exerted on it and inversely proportional to its mass (**F = m** x **a**).
— Newton's Third Law: When a body exerts a force upon a second body, an equal and opposite force is exerted upon the first body: for every action there is an equal and opposite reaction.
— When an object is swung in a circular motion, there is an inward centripetal force working on the string.
— The momentum of an object is equal to the product of its mass and the velocity it has.
— When a moving object collides with another object, its momentum is conserved ($m_1v_1 = m_2v_2$).
—The angular momentum of an object is unchanged unless an external torque acts on it (conservation of angular momentum).
— In spinning objects, the more the object's mass is located towards the center of rotation, the faster the object spins.

3.2.01. PUT THE COIN IN THE CUP

What you need: 1. A paper card and a coin. 2. A cup or drinking glass.



How to do it:

1. Cover the cup with the paper card and put the coin on top of the card.
2. Now ask the students: "How can I get the coin in the cup without lifting the card?"
3. After hearing all the different suggestions, flick the card with your forefinger in a horizontal direction. (In the direction of the card's plane).

What to ask:

1. Why does the coin drop in the cup when the card is flicked away?
2. What held the coin back when the card was moved?
3. What happens to the coin if the card is pulled slowly?
4. Could we pull the card away rather than pushing it away?
5. Where do we see this event applied in daily life?

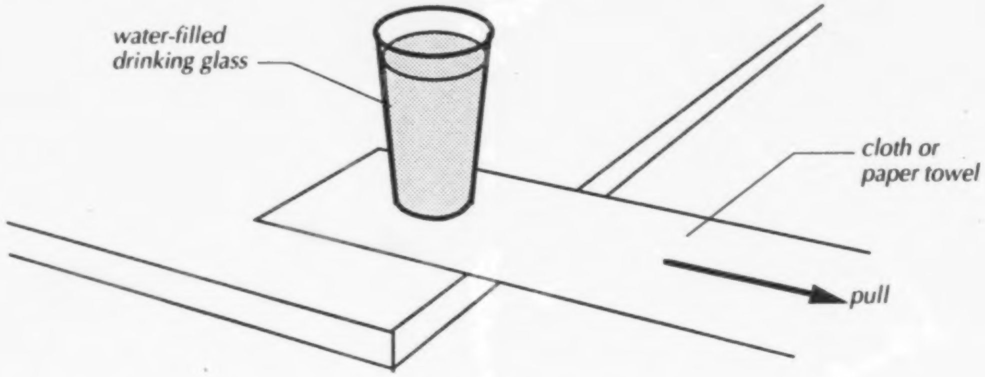
How to explain it:

This event is based on the common characteristic that all objects have and that is **inertia.** The coin lies **inert** on the card and by pushing the card suddenly away, the coin slides over the card and drops in the cup. The more sudden the movement of the card, the more of a tendency that the coin will stay at rest. If the card is pulled slowly away, the coin will move with it. When pulling at the card instead of flicking it, the pulling has to be carried out with a sudden motion as well.

We find this event in our daily life when we stand in a city or school bus, which suddenly starts to move. The bus moves forward with an abrupt motion and the standing person falls backward, because he/she had the inertia, which is also called **the tendency to stay at rest. The larger the mass of an object, the greater its inertia. The inertia of an object is directly proportional to its mass.**

3.2.02. PULL THE TABLECLOTH

What you need: 1. A large beaker (or other glass container with a smooth base).
2. A long, narrow cloth without seam (paper towel will do).



How to do it:

1. Fill the beaker with water and make sure that the outside of the beaker is bone dry.
2. Find a very smooth table top, wipe and dry it off, place the water-filled beaker close to the edge on top of the strip of paper or cloth.
3. Now pull at the paper strip, first slowly until the beaker comes to about 2 cm or so from the edge of the table, then pull with a sudden jerk (do not hesitate!).

What to ask:

1. Why didn't the beaker fall off the table?
2. What made the beaker move closer toward the edge?
3. Why do we need a smooth table top for this demonstration?
4. What is the purpose of the water in the beaker?
5. What events in daily life make use of this principle?

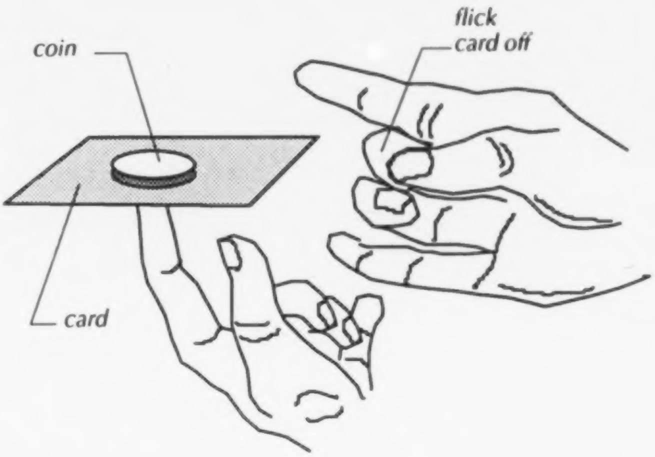
How to explain it:

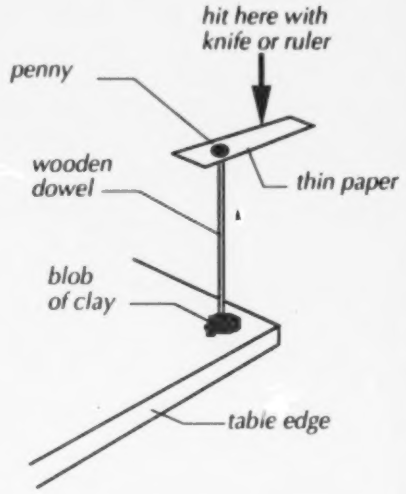
This demonstration can be made most dramatic by placing the beaker about 50 cm from the edge of the table at the start and then pulling it to about 2 cm from the edge. This shows the students that pulling the paper will pull the beaker with it. The slow pull gives enough friction between the paper and the beaker, so that the beaker stays on the paper. The water in the beaker makes it heavier, and **the heavier the object, the greater its inertia or its tendency to stay at rest.** This is why it works easier with the water in it. The table top and the bottom of the beaker need to be smooth and dry, so that a minimum of friction exists when the paper is pulled from under the beaker.

An application of this first part of Newton's First Law in daily life is encountered when we move gravel or other heavy material with a shovel from one place to another: we pull the shovel with a sudden move out from under the gravel or in under the pile of gravel.

3.2.03. THE IMMOVABLE PENNY

What you need: 1. A penny, paper card, and thin paper (onion skin paper) .
2. A short glass tube (or wooden dowel), clamp and stand (or a blob of clay).
3. A sharp long kitchen knife or hacksaw blade.





How to do it:

1. Cut a 3 x 5" card in half, place the penny in the center of the card, and balance the card and penny on your left index finger top (see Sketch A).
2. Flick the card off your finger with your right middle finger (do this horizontally in the plane of the card): penny stays on finger tip!
3. Clamp the glass tube vertically, place a short thin strip of thin writing paper on the top end of the glass tube, weighted by the penny (See Sketch B). (Or mount a dowel vertically on a blob of clay, and place the paper weighted by the penny on the end of the dowel.).
4. Hit the protruding end of the paper with the sharp edge of the kitchen knife or saw blade (or ruler edge) : penny stays on glass tube (or on the dowel end)!

What to ask:

1. What made the penny stay on the finger or on the glass tube (or dowel)?
2. Will the slow removal of the card or the paper have the same effect?
3. What other objects can we use instead of the penny?
4. What implications do you see when doing this on the moon?

How to explain it:

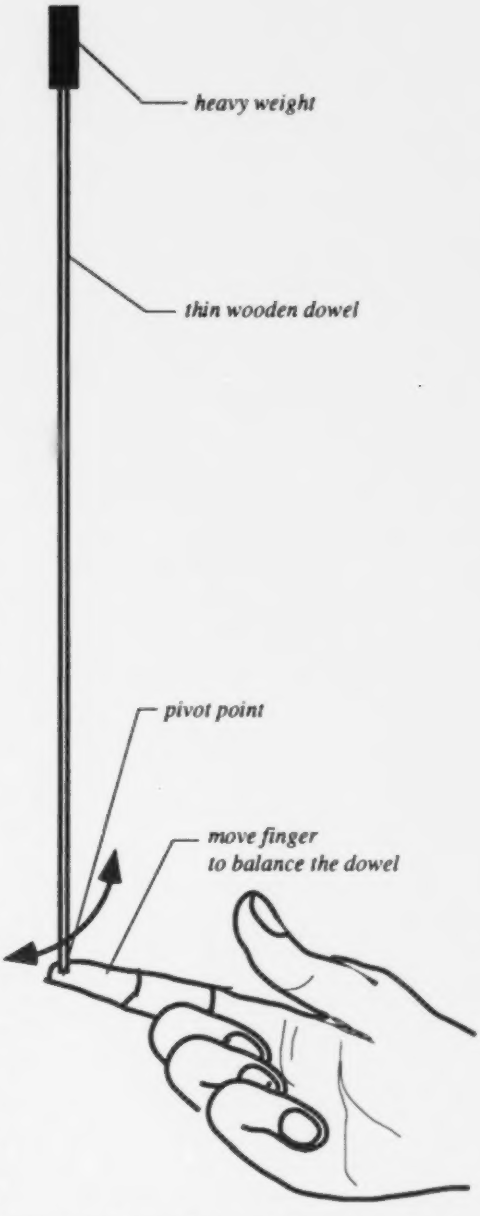
The removal of the card or paper has to be done with a quick action otherwise the **friction** factor will play a role. A slower movement of the card or paper will bring the coin with it. Also the flicking of the card has to be carried out, such that the card will slide off horizontally without tipping the coin. The principle here is that there is enough **inertia** for the penny to stay put.

In hitting the protruding paper with the sharp edge of the knife, the paper folds exactly where the knife hits it, and the sharp edge grabs on to the paper and pulls it away.

Other objects that can be used instead of the penny are: other coins, washers, etc. On the moon this event can be done much easier, as the mass stays the same but the weight is less, and thus the friction between the card and the coin or paper and the coin is less.

3.2.04. ANOTHER BALANCING ACT

What you need: 1. A long, thin wooden dowel (4-6 ft) 3. String or tape.
2. A heavy weight (kg mass or rock)



How to do it:

1. Tie or tape the heavy weight (in the form of weight mass or a heavy rock) to one end of the wooden dowel.
2. Place the other end of the dowel (without the weight) on your index finger, and balance the dowel vertically by moving your finger sideways, forward or backward as needed.
3. Now let a student try to balance the dowel by placing the weighted end on his index finger!
4. After failing to do so, let him turn the dowel upside down and balance it now! Why is it so much easier to hold the dowel vertical on the finger?

What questions to ask:

1. What does Newton's Law say about objects at rest?
2. Would a hievier or lighter object have more innertia?
3. In order for the dowel to stay vertical, where does the center of gravity have to be in relation to the pivot point?
4. Where is the center of gravity of the system located? - When the weighted end is on top? When the weighted end is below?
5. What point do we move when we move our finger on which the dowel rests?
6. Can you find some examples in daily life where this principle is applied?

How to explain it:

The longer the dowel or the heavier the weight sitting on the high point of the dowel, the higher the **center of gravity** of the system. The higher the **center of gravity** of the system, the easier it is to shift the **pivot point** under the center of gravity. This means that it is easier to keep the dowel vertical on the index finger. A second reason for the ease to keep the dowel vertical with a heavy weight on top of it, is that heavier objects have greater innertia - **Newton's Fist Law - First Part says: Objects at rest tend to stay at rest..** This means that it is harder to move heavier objects, and thus is it easier to move the pivot point (this is the point where the dowel rests on the finger) under the center of gravity.

Examples of this principle in daily life we see constantly in circusses, where people balance different loads on top of a long pole. We also see this principle applied when acrobats ride unicycles: the higher the unicycle, the easier it is to ride it. People on stilts can balance them-

3.2.05. PULL THE DOLLAR BILL OUT ?

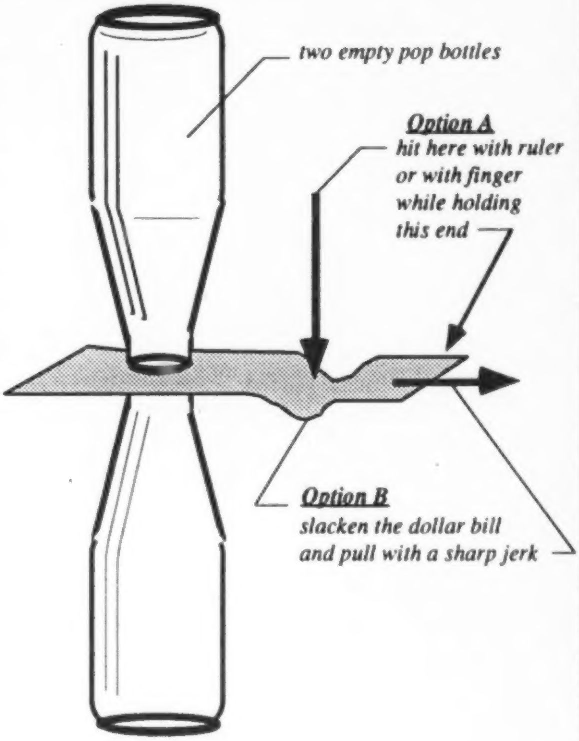
What you need: 1. Two identical, empty soda pop bottles. 2. A crisp dollar bill.

How to do it:

1. Place a crisp dollar bill between two dry soda pop bottles that are put on top of each other like in the sketch (let about an inch stick out on one side).
2. Ask the students: "How can I take the dollar bill without letting the bottle fall?" Ask the students to give you suggestions.
3. Then show that you can actually take the dollar out in two ways:

Option A: Hold the dollar bill at the long end with your left hand, keep the bill straight out and hit with a ruler or with your right-hand middle and index finger vertically down.

Option B: Hold the dollar bill at the long end with your right hand, slacken the bill (by moving your hand towards the bottles), then pull the bill straight out with a sharp movement in a horizontal direction. (see sketch).



What questions to ask:

1. Why do the two pop bottles have to be dry?
2. Which of the two bottles has to be definitely dry on the inside and the outside?
3. What will happen if we pulled the bill using wet bottles?
4. What is the function of the ruler in Option A?
5. In Option B, why do we need to slacken the bill first before pulling?
6. Why did neither of the bottles move with the dollar bill?
7. What does the first part of Newton's First Law state?
8. Would it be harder or easier to pull the bill out with two filled (unopened) bottles?
9. With two unopened bottles, which two factors are increased when pulling the bill out, as compared to using empty bottles?

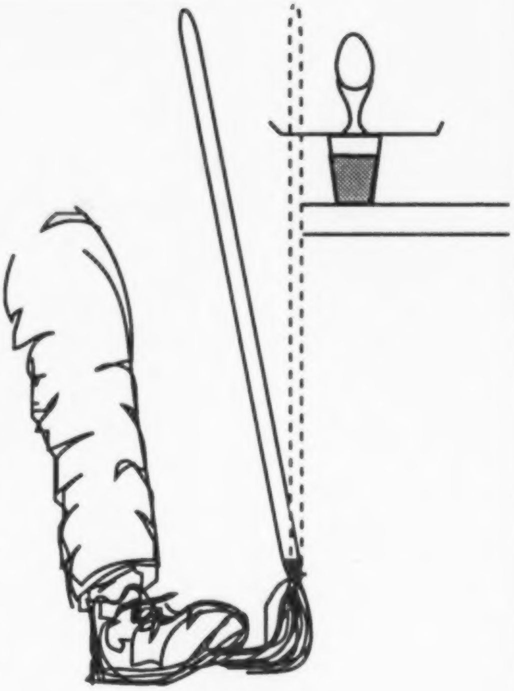
How to explain it:

The pulling out of the dollar bill from in between the two bottles has to be done as fast as possible. This motion is influenced by the **friction** between the paper and the glass rims, which is most likely increased when the bottles are wet - especially the top one. This factor of **friction** is definitely increased when the bottles are unopened (with their caps on), because their mass is greater and thus the force pressing on the dollar bill is also greater. The **innertia** or **tendency to stay at rest** for each of the bottles, however, is also much greater.

It is because of this **tendency to stay at rest** - ***Newton's Law: Objects at rest tend to stay at rest*** - that the two bottles are not moving with the dollar bill when it is moved, provided it is moved out very quickly. The function of the ruler in Option A is to snatch the bill out much quicker than the fingers can. A regular fast pull of the bill is most likely not fast enough and both bottles will move with it. In Option B there is more room (distance) for the hand to move, which prevents the bill to undergo the initial velocity of the hand movement.

Applications of this principle we encounter in tearing a piece of toilet paper off the roll with one hand and when magicians pull table cloths from under dishes and silverware.

3.2.06. GET THE EGG IN THE GLASS



What you need:

1. One raw egg.
2. One egg holder.
3. One aluminum pie plate.
4. A large drink glass.
5. A household broom.

How to do it:

1. Fill the drink glass three quarters full with water.
2. Put the empty pie plate on the glass and center the egg holder and raw egg on the pie plate directly over the glass.
3. Place the glass with everything else on top, close to the edge of the table such that the rim of the pie plate hangs over the table edge (see Sketch).
4. Ask the students: "How can I get the egg in the glass with the broom without breaking it?" Anticipated answer: "Have no idea!"
5. Hold the broom directly in front of the set up, push down on it so the sweep part of the broom bends. Place one foot on the broom while holding back the wooden handle, then suddenly release the pole and flick it hard against the pie plate (see Sketch).

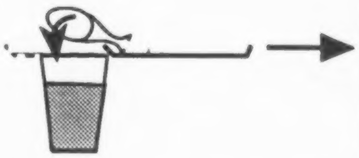
What questions to ask:

1. What made the egg fall exactly in the glass?
2. What was the function of the water in the glass?
3. What would happen if we had a plate without a rim on the glass?
4. Why did the pie plate have to protrude over the table edge?
5. Would any other object in the egg holder end up in the glass?

How to explain it:

The broom stick hit the edge of the pie plate without hitting the glass or the egg, because its motion was stopped by the table edge.

This sudden force moved the pie plate out from under the egg carrying with it the egg holder, as this was caught by the plate's rim (see Sketch).The egg was **at rest** and **tended to stay at rest (first part of Newton s First Law).** The water was needed to catch the raw egg and prevent it from breaking. Any other object on the egg holder would have fallen in the glass, provided it has a heavy enough mass (and thus have enough inertia).

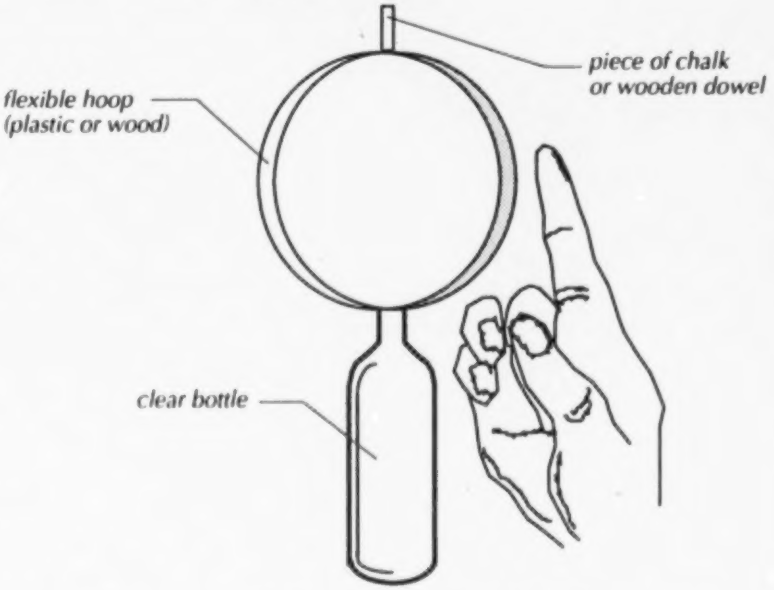


3.2.07. GET THE CHALK IN THE BOTTLE

What you need: 1. A flexible plastic hoop (cut from a polyethylene container).
2. A bottle with a narrow neck. 3. A small piece of chalk.

How to do it:

1. Cut a narrow (1 cm wide) hoop from a flexible polyethylene container.
2. Place it on the mouth of the bottle and center a small piece of chalk vertically over the opening of the bottle (put one eye over the chalk and this should line up with the bottle mouth).
3. Flick the hoop with your finger from under the chalk by hitting the hoop on the inside (but holding the finger on the outside of the hoop before the flicking itself).
4. Let students observe carefully where you hit the hoop without telling them what you are doing.
5. Let students try to get the chalk in the bottle (those that know where to hit the hoop will be able to do it, others will not).


piece of chalk or wooden dowel
flexible hoop (plastic or wood)
clear bottle

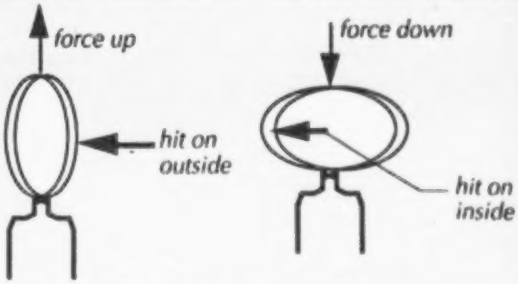
What to ask:

1. Did you observe where the hoop was hit with the finger?
2. Why does the chalk fly off if the hoop is hit on the outside?
3. What force acts on the chalk when the hoop is hit on the outside?
4. What will the flexible hoop do if it is hit on the outside or on the inside?

How to explain it

The demonstration can be used to focus students' attention on careful and accurate observation skills. Without telling them where the hoop is hit, they should be able to find out for themselves.

When the hoop is hit on the inside, it flattens and slips out from under the chalk. When it is hit on the outside, the force is upwards, and the chalk gets pushed up (see sketches on the right).

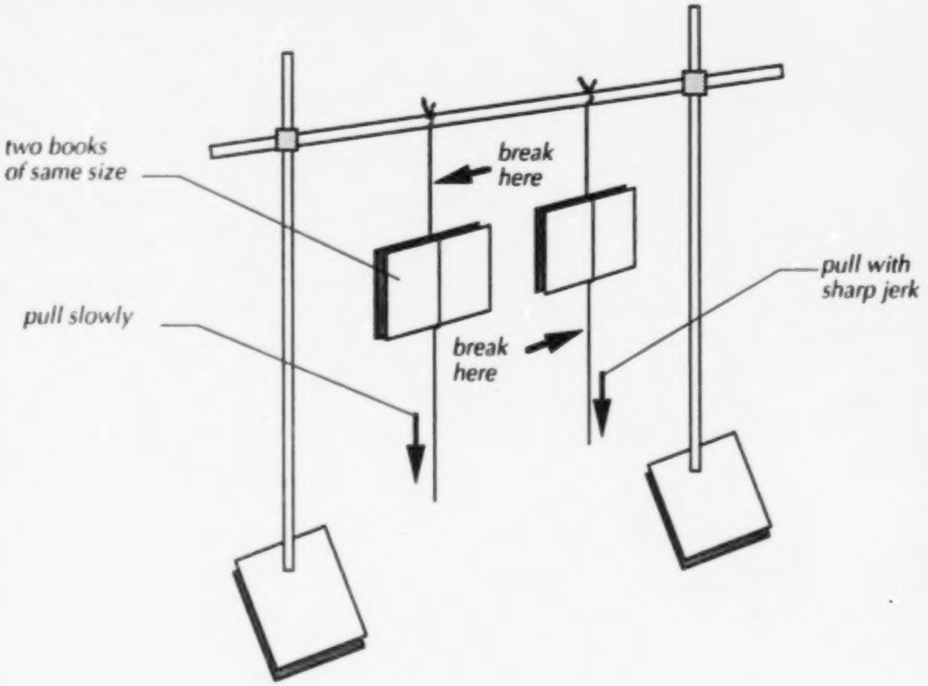


3.2.08. BREAK THE STRING WHEREVER YOU WANT

What you need: 1. Two paperback pocket books (same thickness).
2. A horizontal stand and sewing thread.

How to do it:

1. Tie threads around each of the books, such that a loose end comes out from each side of the book.
2. Tie one end of the thread around the horizontal stand (or let a student hold it) and let both books hang side by side (or let another student hold the other book) (see sketch).
3. Now ask the students: "Where do you want me to break the thread of book No. 1? Above or below the book?" If they answer: 'above the book,' pull slowly at the thread.
4. For book No. 2, pull the thread with a short jerk: thread will break below the book!



What to ask:

1. Do you see any difference in the way the thread was pulled?
2. Why does a slow pull at the thread break it above the book?
3. Why does a sharp jerk break the thread below the book?
4. Which of the two breaks makes special use of the book's inertia?

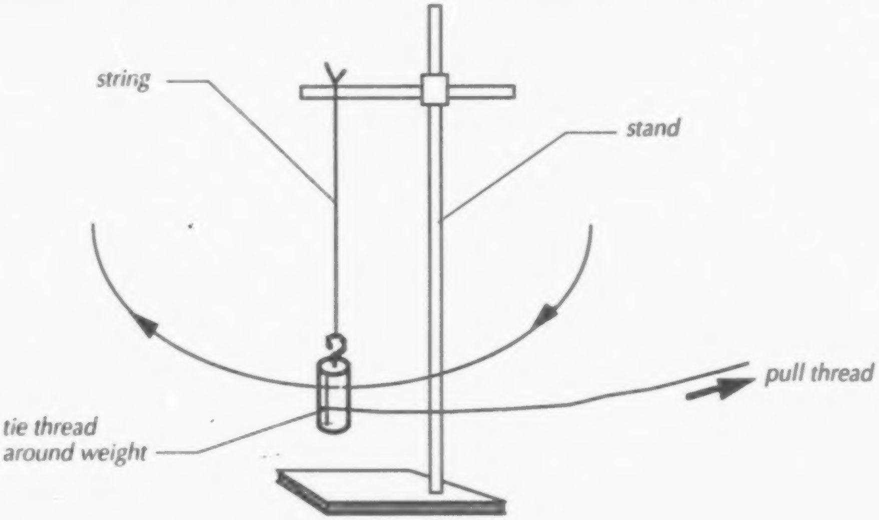
How to explain it:

By pulling the thread slowly, we are not only putting a strain in the thread, but in the thread above the book, the book's **weight** adds to this pull. Thus compared to the **strain** below the book, this is much larger and the thread snaps wherever the strain is highest.

When a sharp jerk is exerted on the thread, the **inertia** of the book keeps the strain below the book the highest. Although there is some strain in the thread above the book, compared to that below the book, the strain in the latter is still higher, and the thread snaps below the book.

3.2.09. WHAT BREAKS THE THREAD ?

What you need: 1. A 1 Kg mass or a stone of about 1 Kg weight.
2. A medium size string and sewing thread. 3. A stand and clamp.



How to do it:

1. Hang the weight on a string tied to the clamp and stand.
2. Tie a length of sewing thread around the weight and pull slowly on the thread and show to students that it is possible to move the weight up high without breaking the thread.
3. Let the weight hang vertically and give the thread a sudden pull. Ask: "What property of the weight made the thread break?"
4. Tie another thread to the weight, pull the weight and let it swing back and forth, but let your hand swing in phase with it (holding the thread), then suddenly stop the hand. Ask: "What property of the weight made the thread snap?"

What to ask:

1. Which part of Newton's First Law was the first break based on?
2. What events in daily life are based on this principle?
3. Which part of Newton's First Law was the second break based on?
4. Can you mention any events in our daily life that are based on this second principle?

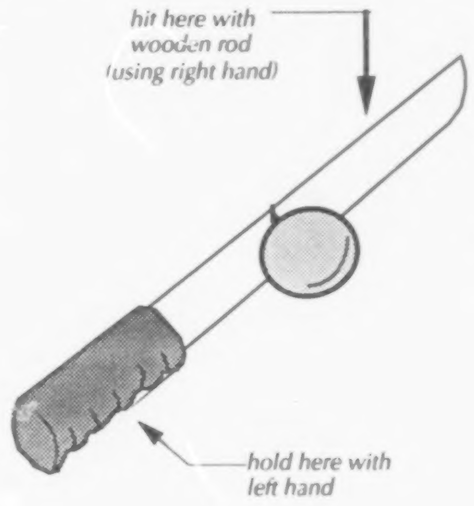
How to explain it:

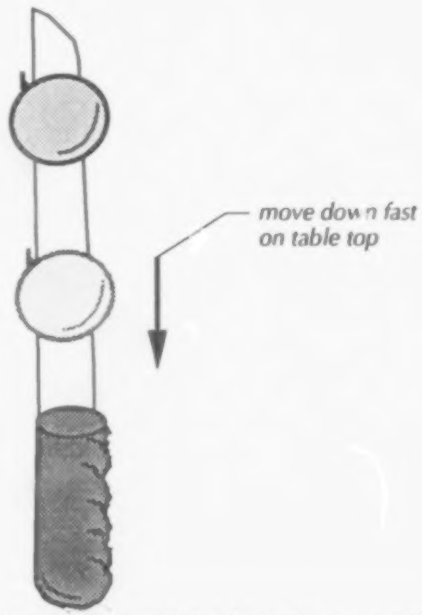
When the thread was broken the first time around, it was done by pulling the thread with a sharp jerk. The weight was **at rest** and **it had the tendency to stay at rest.** (First part of Newton's First Law.) An application of this principle in daily life is pulling a table cloth out from under dishes, pushing a shovel under a heap of gravel, etc.

Breaking the thread the second time around was caused by a sudden stop of the moving hand, when the weight was still moving. The **weight was in motion and it tended to stay in motion (in a straight line)** (second part of Newton's First Law). Events in daily life based on this principle are for example: the tightening of a loose axe on its handle, the sudden stop of a bus and the tendency of the passengers to keep moving forward, etc.

3.2.10. THE APPLE AND THE KNIFE

What you need: 1. Two fresh apples, a long kitchen knife.
2. A wooden rod or stick (to hit the knife with).





How to do it:

1. Press the kitchen knife about 1/4 way through the first apple, hold the knife horizontally and hit the end of it with the wooden rod (see Sketch A). The apple will split in half illustrating the first part of Newton's First Law.
2. Now push the point of the kitchen knife all the way through the second apple. Ask the students: "How can I get the apple to slide closer to the handle?"
3. Hold the knife vertically above the table with the point upwards. Move the knife fast to the table top, hitting it hard with the knife handle. The apple will slide closer to the handle, illustrating the second part of Newton's First Law (see Sketch B).

What to ask:

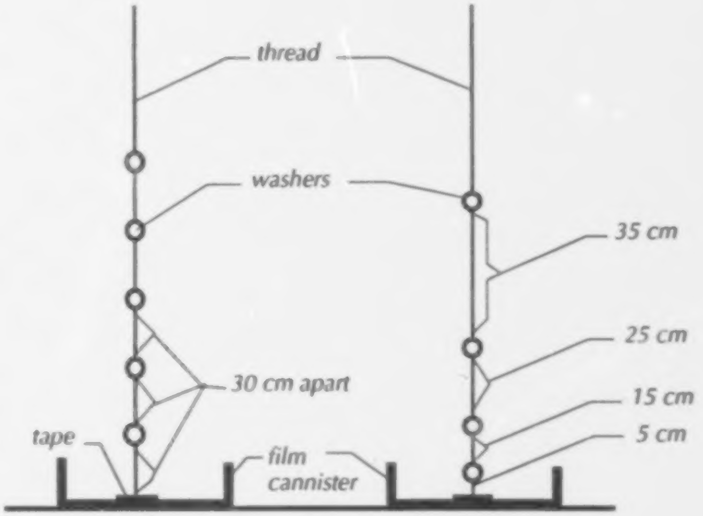
1. Why did the first apple split in two halves?
2. Was it the apple or the knife that followed Newton's Law?
3. In sliding the apple, which of the two (apple or knife) followed the second part of Newton's First Law?
4. What other daily examples can you name that are based on the first part and second part of Newton's First Law?

How to explain it:

Newton's First Law states that: **an object at rest tends to stay at rest**, and **an object in motion tends to stay in motion in a straight line**. The first apple split in two halves, because it tended to stay at rest when the knife was hit. The second apple slid closer to the knife handle because it tended to stay in motion when the knife was suddenly stopped by the table top.

3.2.11. THE FALLING WASHERS

What you need: 1. Six or seven metal washers)
2. A strong thin thread) for each demonstration.
3. An old film canister)



Sketch A **Sketch B**

How to do it:

1. Tie the six or seven washers exactly 30 cm from each other on the thread and tape the end of the thread to the film canister, such that the first (lowest) washer is 30 cm above it.
2. Stand on a chair and hold the thread tight above the canister, while this latter is lying on the floor. Ask students: "What kind of tapping sound will the washers give us when I let them fall; even or faster and faster?" Now drop the washers (see Sketch A).
3. Tie seven washers to another thread the following distances from each other: canister to first washer 5 cm, the next six washers: 15, 25, 35, 45, 55, and 65 cm from each other respectively.
4. Repeat point 2 (see Sketch B). Observe the clicks.

What to ask:

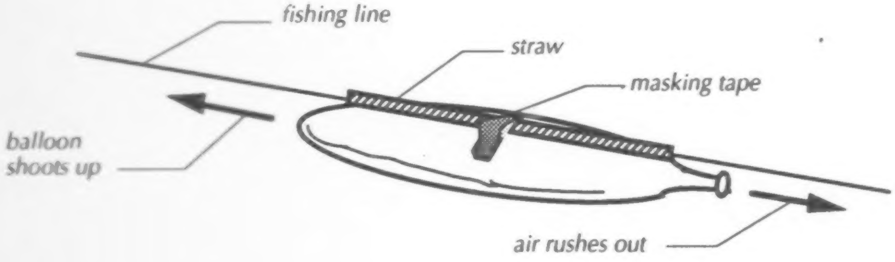
1. What kind of tapping sound did the washers give us in demonstration A, compared to that in demonstration B?
2. Which of the seven washers had the highest velocity when hitting the bottom?
3. What kind of motion is the free fall of the washers?
4. What gives a falling object its acceleration?

How to explain it:

The falling washers are all subjected to gravity, which force imparts an **accelerated motion** to each of them. Newton's Second Law states that **F = MA** (F = force, M = mass, and A = acceleration), and as the force and mass of the washers are equal, the acceleration of each of the washers is the same. The higher, the larger the velocity of the washer hitting the canister. The distances between the washers in B were obtained from $S = 1/2at^2$ (where S = distance, a = acceleration, and t = time).

3.2.12. THE BALLOON RACE

What you need: 1. Two long cylindrical balloons. 2. A roll of fishing line (or smooth string).
3. Two straws and masking tape.



How to do it:

1. Divide the class in two groups: there is going to be a race!
2. Have one student of each group tie one end of 10 m length of fishing line to a pipe (or fire sprinkler) close to the ceiling at one end of the classroom (in the front).
3. Bring the other end of the fishing line to the rear of the classroom and have another student of each group push the fishing line through the straw, and hold the line tight.
4. Now have another student of each group blow up the balloon and hold the mouth closed (do not put a knot in it), and hold the balloon under the straw with its mouth facing the rear of the room.
5. Let another student tape the balloon to the straw (one strip of tape over the middle of the straw). You are now ready for the race.
6. Have the students release the balloon on the count of three.

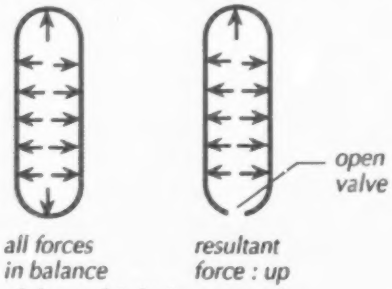
What to ask:

1. In which direction did the air of the balloon go?
2. What made the balloon shoot up?
3. Will a smaller or larger balloon shoot up faster?
4. If we want the balloon to shoot down, which way do we have to face the balloon's mouth?

How to explain it:

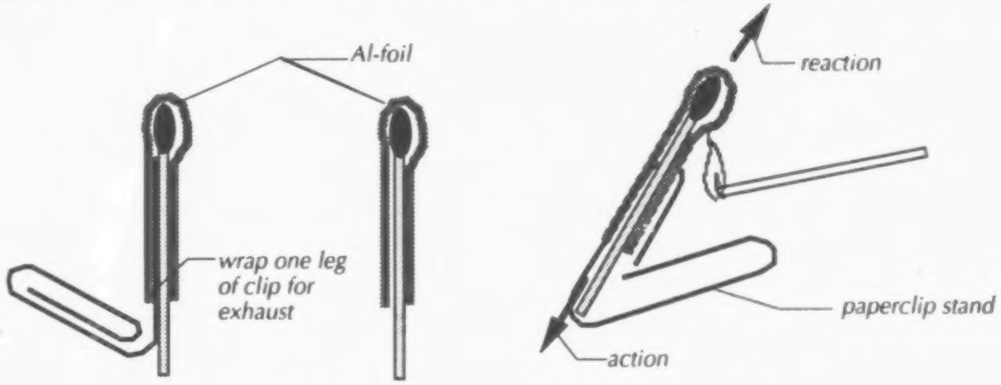
At the time that the balloon was held with its mouth closed at the rear of the room, all forces inside the balloon were balanced by an **equal and opposite force**. This will also be the case when we put a knot in the balloon's mouth or in the case of a closed pressured chamber in space (see Sketch 1 on the right).

When the balloon is released, the downward force is eliminated, and the resultant force is upwards. This is quit similar to the operation of a pressure chamber in a rocket or satellite. When a left turn has to be made, a valve on the right hand side of the vehicle is opened.



3.2.13. THE MATCH MISSILE

What you need: 1. A box of wooden matches, a box of paper clips . 2. A roll of aluminum foil.



Sketch A *Sketch B*

How to do it:

1. Distribute two matches and two paper clips and a strip of aluminum foil to each pair of students (let students work in pairs).
2. Demonstrate to students how to make the missile: a. Wrap the match airtight with one end of the paper clip against the match stick (see Sketch A) and slide the clip out (this provides the exhaust pipe). b. Bend out another clip to make a stand and lay the wrapped match against it (see Sketch B). c. Heat the wrapped match head with another lit match.
3. Let students try to make the farthest reaching missile.

What to ask:

1. What makes the "missile" shoot up?
2. What would happen if we heated the wrapped match without providing for an exhaust?
3. Does the angle of the bent up clip make any difference in the distance that the missile can reach? Try different angles.
4. What are other factors that influence the reach of the missile?

How to explain it:

When wrapping the match (missile) with aluminum foil, we need to lay one leg of a paper clip (bent out) against the wooden stick, to provide an exhaust for the expanding gases when the match ignites. Sometimes when this exhaust is not working properly, a bursting of the aluminum foil near the match head will occur.

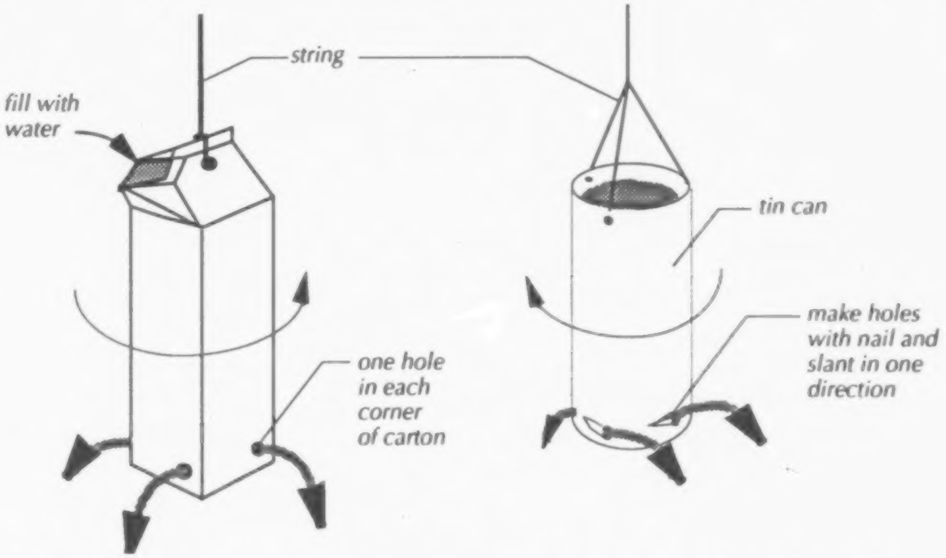
Factors that influence the reach of the missile would be:

a. the weight of the missile—in our case the Al-foil, the less used, the lighter, but the less strong to keep the gases in.
b. the match itself—some have larger heads, which would provide more power (try wrapping in an additional match head).
c. the angle of blasting—45° angle is optimal; larger or smaller angles with the horizontal plane will give shorter distances.

This event is based on Newton's Third Law, which states that: **For every action, there is an equal and opposite reaction.**

3.2.14. THE MILK CARTON SPRINKLER

What you need: 1. An empty milk carton (2 l) or large tin can. 2. A length of sturdy string.


string
fill with water
tin can
make holes with nail and slant in one direction
one hole in each corner of carton

How to do it:

1. Make four small holes, one in each right hand lower corner, in the sides of the milk carton.
2. Tie the string through a hole in the top of the carton, to hang it over the sink from a support (or from your hand).
3. Fill the carton full with water over a sink and let it hang from the string, and observe!

What to ask:

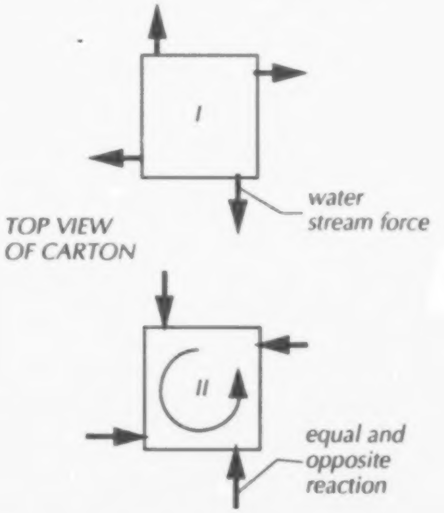
1. Looking from above, which way does the carton turn?
2. Is it possible to turn the carton in the opposite direction?
3. Where do the holes have to be placed in order for the carton to move in the opposite direction?
4. When would the carton stop turning?
5. What principle is this event based on?

How to explain it:

This event is based on the **Third Law of Newton: action is reaction.** The action here is the water spouting out from each lower right hand corner of the side of the carton (see Sketch 1).

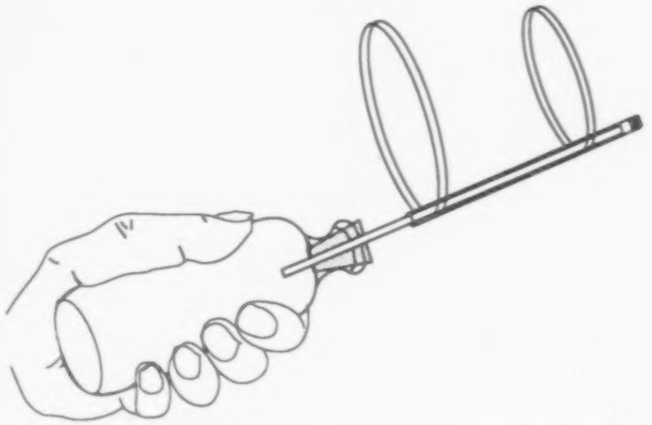
The reaction is an equal and opposite force on the carton (see Sketch 2), which makes the carton turn counterclockwise. In order to make the carton turn clockwise, the holes have to be placed in the left hand lower corner of each side.

A tin can could replace the carton by making nail holes near the bottom and slanting the nails in one direction.


I
water stream force
TOP VIEW OF CARTON
II
equal and opposite reaction

3.2.15. THE STRAW ROCKET

What you need: 1. A plastic flexible bottle. 2. Two drinking straws of two different sizes.
3. Some molding clay and construction paper.



How to do it:

1. Prepare the bottle starter by putting a roll of molding clay around one end of the smaller straw and fitting it into the mouth of the plastic flexible bottle - test for leaks by plugging the other end of the straw with a finger, then squeezing the bottle: this should feel hard to squeeze when there are no leaks.
2. Prepare the rocket by taping two paper loops to the larger straw. One smaller loop to the front end and a larger loop to the back end. Stuff the front end of the straw with a blob of clay.
3. You are now ready to launch the rocket. Place the larger straw over the smaller one, hold the paper loops on the top side of the rocket with another straw, and squeeze the bottle with a sudden motion.

What questions to ask:

1. What made the rocket move forward?
2. Why does the smaller straw have to fit tightly in the bottle?
3. What is the function of the blob of clay in the larger straw?
4. What is the function of the paper loops?
5. What initial action gave the rocket its energy to shoot forward?

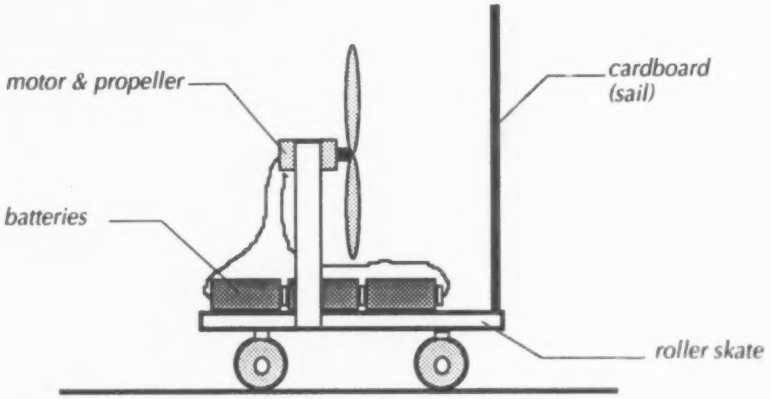
How to explain it:

By squeezing the plastic bottle, air is blown through the smaller straw into the larger straw. As this latter one is plugged at the front end, a higher pressure is built up in the larger straw and this makes the rocket shoot forward. As **Newton s Law** states: **For every action there is an equal and opposite reaction.** The action here is air shooting out of the rear of the rocket (larger straw), and the reaction is that the rocket moves forward. The function of the paper loops is to keep the straw floating in a horizontal direction.

Toys that shoot plastic balls by squeezing a plastic gun, and air guns (Beebee guns) are applications of this basic principle of **action is reaction.** Letting go of a blown up balloon (without putting a knot in it) is another example. The action is: air moving out of the balloon in one direction, and the reaction is: the balloon moving in the other direction.

3.2.16. BLOW YOUR OWN SAIL ?

What you need: 1. A roller skate, a small motor and propeller.
2. Six 1.5V C-size batteries & 2 short lengths of bell wire.
3. A piece of cardboard.



How to do it:

1. Mount the motor and propeller by means of wooden or metal strips on one end of the skate.
2. Tape the six batteries three by three in series together, and place them on the skate. Connect the wires from the batteries to the motor (leave the connection of one lead off for the moment).
3. Tape a piece of cardboard to the other end of the skate, such that the propeller blows air against the cardboard sail.
4. Ask the students: "W hat will the skate do when the fan is turned on?" Let them keep their predictions in their mind. Now complete the circuit and turn on the propeller.
5. Ask the students: "W hat will the skate do when the sail is taken off?" Take the cardboard away while the propeller is still turning. Observe the movement of the cart/skate.

What to ask:

1. What forces are acting on the skate with fan on and sail on?
2. What forces are acting on the skate with fan on and sail off?
3. Why does blowing your own sail in a sailboat on a windless day not make you move forward?
4. What is the propeller blowing against when the sail is taken off?

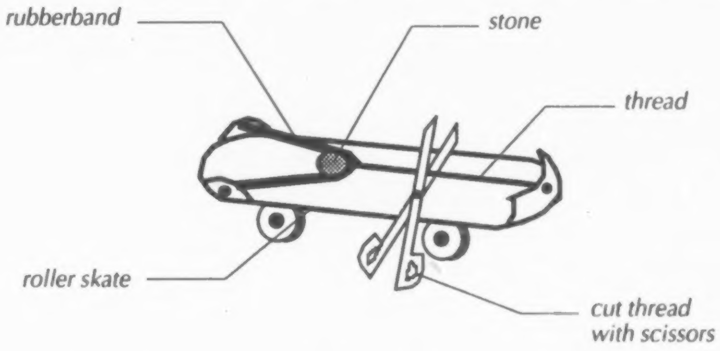
How to explain it:

With the propeller blowing against the cardboard, two **forces** of the same size but **in opposite directions** are working on the skate. When the cardboard or sail is taken away, that force is also eliminated, leaving one force in the opposite direction of the blowing as the resultant force. For the same reason, blowing your own sail on a windless day will not work, as two equal and opposite forces are working on the boat: one against the sail and one against the boat itself in the opposite direction, but as the sail is attached to the boat, the two forces compensate each other.

. The same two equal and opposite forces are present when we push down on the table top. We feel the table pushing back against our hand.

3.2.17. THE RECOILING SKATE

What you need: 1. A roller skate and a stone. 2. A heavy rubber band and a piece of string.



How to do it:

1. Cut the rubber band and attach the two ends to the front sides of the skate.
2. Tie a string to the center of the rubber band and pull it back like a catapult (see sketch) and attach the other end of the string to the back of the skate.
3. Place a medium size stone in front of the rubber band and cut the string with a pair of scissors (make sure that you do not touch the skate when cutting the string).

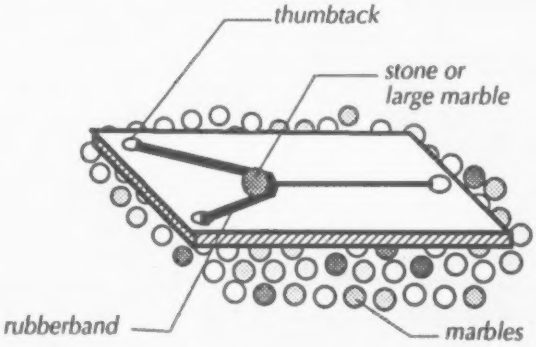
What to ask:

1. What did the skate do when the stone was flung to the front?
2. How far did the skate recoil, and how far did the stone fly?
3. Would the skate recoil more or less with a larger stone?
4. What events in daily life would be similar to this one?
5. What other objects or set-ups could we use instead of the skate?

How to explain it:

The action in this demonstration is the flinging of the stone by the rubber band to the front of the skate. The reaction is that the skate rolls backwards. The **Third Law of Newton** states that the force flinging the stone is equal to the force pushing the skate back. Because the masses of the two objects are not equal, the accelerations or velocities of the objects are also different. The **momentum** imparted on the stone is equal to the momentum of the skate: $M_1V_1 = M_2V_2$, where M_1 = mass of stone, V_1 = velocity of stone, M_2 = mass of skate, V_2 = velocity of skate. **This conservation of momentum** principle shows clearly in this event, where the stone has a much higher speed than the skate.

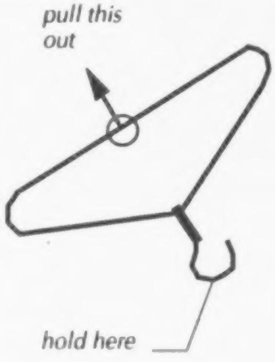
Other equipment that can replace the skate would be: a wooden board on marbles or straws. The rubber band and string could be attached to the board with thumbtacks (see sketch on right).



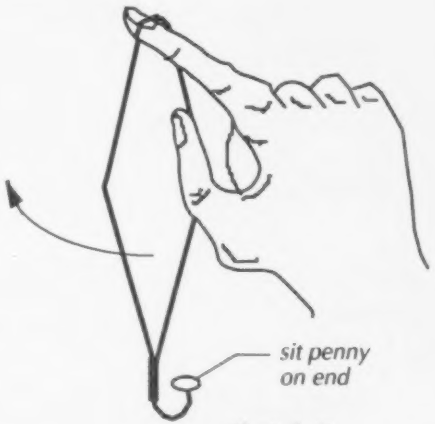
3.2.18. THE STICKY PENNY

What you need: 1. A wire coat hanger, a penny (or any other coin).

How to do it:



Sketch A



Sketch B

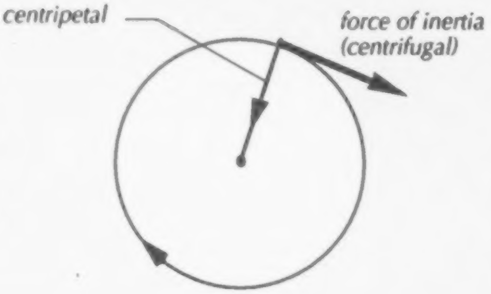
1. Pull the middle of the longest straight part of the hanger out (see Sketch A) and shape it into a long narrow shape (Sketch B).
2. Let the hanger hang on your right index finger (left, if you are left handed) and place a penny on the end of the wire (sometimes this end needs to be filed, especially if it is not flat).
3. Start to swing the hanger—first slowly back and forth, then do full loops (this needs a little practice, without dropping the penny).
4. Swing it slower (when ending the swing) and try to catch the penny. When suddenly stopping this swinging, the penny will fly off. To make this same principle more dramatic, immediately follow it up with Event 2.19.

What to ask:

1. How could the penny stay stuck against the end of the hanger?
2. What kept the penny against the coat hanger?
3. Would the coin still stick to the hanger if the swinging was done much slower?
4. What events in our daily life are similar to the moving penny?

How to explain it:

The spinning of the penny gives it a **centripetal** force pulling the coin inward towards the finger (center of rotation). By moving the penny, it tends to stay moving in a straight line. This **force of inertia** (centrifugal force) keeps the penny against the end of the coat hanger. The faster the spinning, the larger this centrifugal force; the slower the spinning, the smaller this force is, that keeps the coin up against the hanger. This is why the coin falls when the spinning is done too slow.



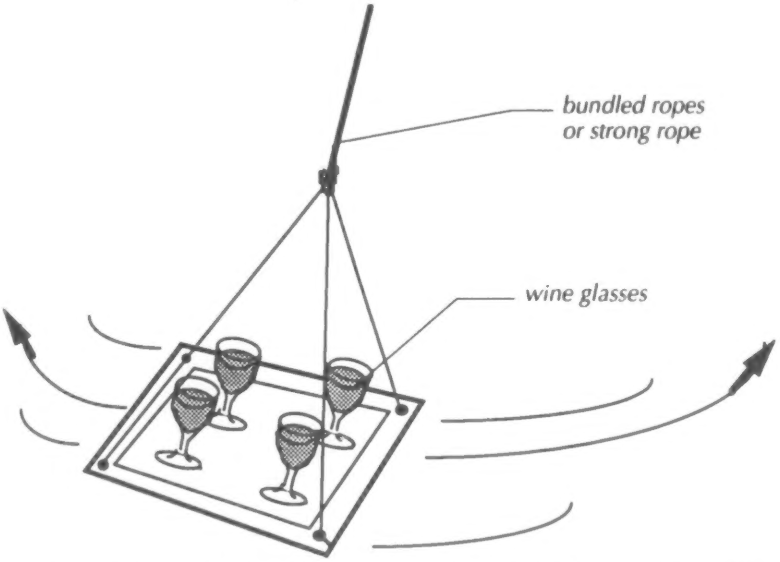
Centrifugal forces are applied in the automatic cloth washer, where the drum filled with clothes and water spins fast to separate the water from the clothes. **(The tendency to stay moving in a straight line causes this force of inertia or centrifugal force).**

3.2.19. THE FLYING WINE GLASSES

What you need: 1. Three or four plastic wine glasses. 2. A sturdy plastic try (or cardboard sheet). 3. A strong flexible rope.

How to do it:

1. Drill four small holes in the four corners of the plastic tray.
2. Tie four pieces of rope to each corner of the tray (through the hole), bring them together to the center above the tray while it lies horizontally on the table, and tie a knot in all four strings together.
3. Tie another knot at the end (about 1 m away) of the bundled rope.



4. Place the four wine glasses on the tray and fill them 3/4 full with red colored water (or real wine for that matter).
5. Start swinging the tray with the glasses and swing full loops, making sure that the tension in the rope is maintained.
6. To stop: decide on the down swing to stop and slacken the tension by moving your hand in a horizontal direction - **practice this outdoors!**

What to ask:

1. What made the wine stay in the glasses even when inverted?
2. What kept the glasses pressed against the tray?
3. What is the tension in the rope, while swinging, an indication of?
4. What would happen if we lost this tension in the rope, while the tray was in an upside down position?
5. How can we keep a rather even tension in the rope when swinging?

How to explain it:

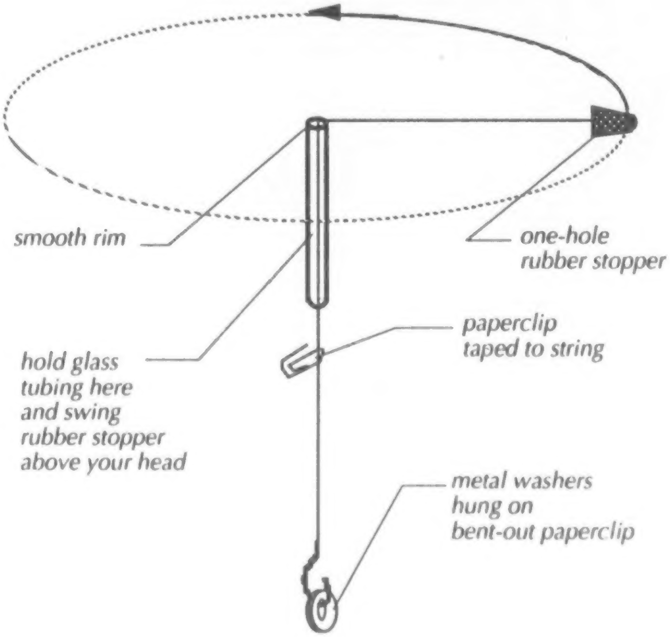
While in motion, the wine as well as the wine glasses tend to move in a straight line (**second part of Newton's First Law**). As they are kept in a circular motion, they are pressed against the tray (centrifugal force) and an equal center seeking force, **centripetal force,** is felt as a tension in the rope. The faster the swing, the stronger the tension in the rope. A rather even tension in this rope may be obtained by swinging the tray back and forth in the beginning and making the full loops when the swing almost reaches the horizontal position. (Practice by swinging a stone tied to a string.)

3.2.20. MEASURE THE CENTRIPETAL FORCE

What you need: 1. A one-hole rubber stopper. 2. Metal washers, a strong string, paper clips.
3. A piece of glass tubing (about 15 cm long and nicely rounded off at the ends).

How to do it:

1. Thread the string through the glass tubing and let about 50 cm come out on each end of the tubing.
2. Tie the one-hole rubber stopper to one end and a paper clip to the other end of the string. Bend the paper clip leg somewhat out.
3. Hang a few washers on the bent-out paper clip and tape another paper clip about 30 cm from the paper clip end to the string (to be used as an indicator to see whether the string is sliding up or down the tube).


smooth rim
one-hole rubber stopper
paperclip taped to string
hold glass tubing here and swing rubber stopper above your head
metal washers hung on bent-out paperclip

4. Twirl the rubber stopper above your head by holding the glass tubing and swinging the stopper. Try to keep the paper clip indicator at the same height by adjusting the twirling speed.
5. Add more washers to the bottom paper clip: "What do you have to do with the twirling speed?"

What to ask:

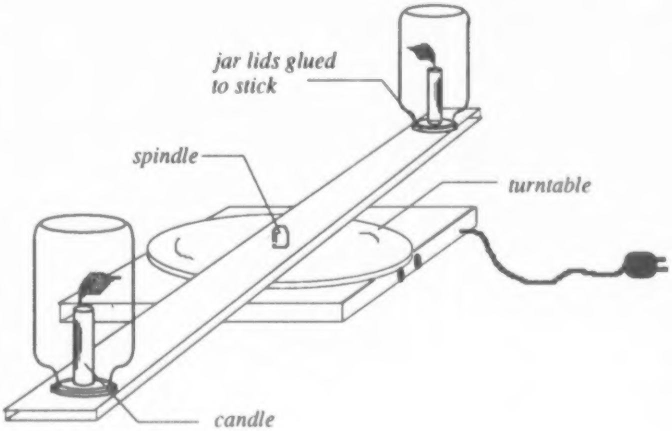
1. What is the relationship between rotational speed and number of washers?
2. What relationship is there between speed of rotation and the diameter of rotation?
3. What relationship is there between diameter of swinging object and the number of washers?
4. How can we measure the centripetal force of the swinging stopper?

How to explain it:

Holding the diameter of the swinging object (length of string above the tubing) constant, the faster the **speed of rotation** (number of revolutions per second), the more washers have to be hung on the bottom paper clip. The same goes for increasing the diameter when the speed is held constant. With the same number of washers, the smaller the diameter, the higher the speed of rotation, in order to keep the forces in balance. The centripetal force is the total weight of the washers hung on the paper clip.

3.2.21. THE GRAVITY MACHINE (I)

What you need: 1. An old variable speed turntable or simple Lazy Susan.
2. Two identical empty jam jars (with lid). 4. Two medium size candles.
3. A wooden stick (double the width and length of a 30 cm ruler). 5. Epoxy glue or some other strong cement.



How to do it:

1. Make a small hole in the center of the wooden stick, such that it will fit tightly over the spindle of the turntable.
2. Cement the two jar lids upside down on each end of the wooden stick with epoxy glue or other strong cement.
3. Attach each candle to the center of each of the jar lids (with candle wax).
4. Light the candles and show what the flames are doing when the turn-table is switched on (use the low speed for this).
5. Ask students to predict what the candle flames will do when the glass jars are screwed on just before the table is turned on.
6. Screw the glass jars over the burning candles into the lids and immediately switch on the turntable (using higher speeds). Observe the flames!

What questions to ask:

1. What made the flames point towards the center of the turntable?
2. Which way does a candle flame point in still air? Why?
3. What does the spinning of the jars do to the air molecules in the jar?
4. What part of the jars would contain denser air?
5. In which direction did the spinning create a gravitational force?

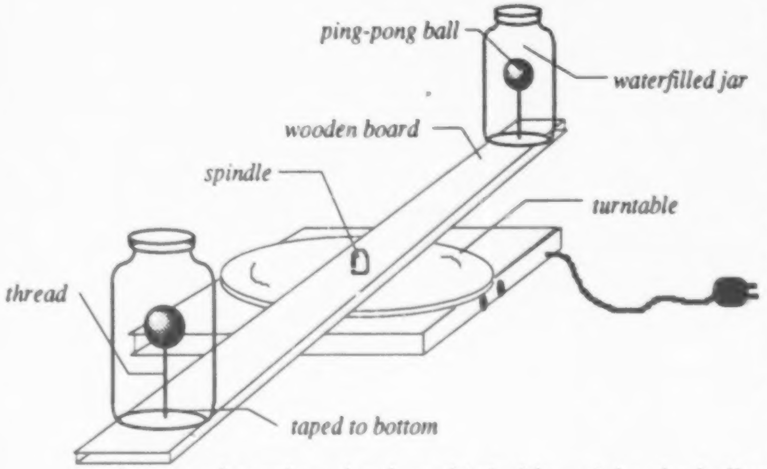
How to explain it:

The spinning of the jars on the turntable created a centripetal force (center seeking). The air molecules in the jars are put in motion and tend to stay moving in a straight line. As the jars move in a circular motion, the air molecules tend to move toward the outside (farthest from the spindle), thus making the outside part of the jars more dense. Since **candle flames always point towards less dense areas of air** - in still air they point upwards as the heat makes the air above the flame less dense - in the jars they point towards the inside part or towards the center of the turntable.

In space, satellite stations' gravity will most likely be created in the same fashion. Other applications are found in amusement parks where we find rotating drums and motorcycles riding

3.2.22. THE GRAVITY MACHINE (II)

What you need: 1. Two identical empty jam jars (with lid). 2. Two ping-pong balls, thread, and tape. 3. A sturdy wooden board. 4. A turntable or "lazy susan".



How to do it:

1. Drill a small hole in the center of the wooden board, such that it will fit tightly over the spindle of the turntable; and fit the board on it.
2. Tape the two jars right side up against the ends of the board (see Sketch).
3. Attach a short piece (about 10 cm) of thread to each of the ping-pong balls, and attach the other end of the thread against the bottom of each of the jars (make sure that when the thread is held up tight, the ball will only come up to about three quarters of the jar's height).
4. Fill the jars full with water (the ping-pong balls should be totally submerged under water and hanging up from the thread), and close tightly.
5. Before rotating, ask: "Which way will the ping-pong balls move, when the table rotates?" Anticipated answer: "Outward, or against the direction of the rotation". Now switch the turntable on, and observe! (or turn the lazy susan).

What questions to ask:

1. Which way did the ping-pong balls move towards during rotation?
2. Why did the ping-pong balls hang upwards in the water?
3. What would you expect the ping-pong balls to do if they were hung from the lids in air-filled jars?
4. What would golf balls do, when hung by threads from the lids in waterfilled jars? In air-filled jars?
5. Which way would a helium-filled balloon (tied to a thread) in an accelerating bus move to? Forwards or backwards or stay stationary?

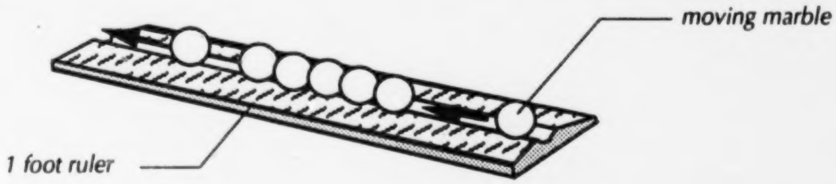
How to explain it:

Just like the candle flames in the former Event : **THE GRAVITY MACHINE I**, the ping-pong balls are lighter than water, and **tend to float towards areas of lesser density.** As soon as the water-filled jars are being rotated, the water molecules are flung outward, making the outside of the jar denser and the inside (toward the center of the turntable) less dense. This is the cause of the balls to be flung inwards.

If the ping-pong balls were suspended from the lid in air-filled jars, the balls would fling outwards, as they are heavier than air. So will golf balls in water or air behave. But helium-filled balloons in a suddenly moving bus would move forward when the bus accelerates, and move backwards when the bus suddenly stops.

3.2.23. THE FUNNY MARBLES

__What you need__: 1. A plastic ruler (30 cm long, with center groove). 2. Seven identical marbles.



__How to do it:__

1. Place the seven marbles in the groove of the ruler all next to and touching each other.
2. Now take one marble and let it roll from about 5 cm away, with some speed against the other six. Ask: "How many will keep on rolling?" (only one will move away).
3. Place the marbles back on their original position and do the same with two marbles bumping against the remaining five. Ask the same question.
4. Now separate four and before letting them roll against the remaining three, ask the students: "How many marbles will move away?"

__What to ask__:

1. When one marble bumps against six, why does only one marble move away?
2. Are the other five marbles moving much after the collision?
3. How many would move away if five marbles were pushed against two?
4. Would a marble twice as heavy also move only one away?
5. Would the end marble move also faster when one is hitting the row with a faster speed?

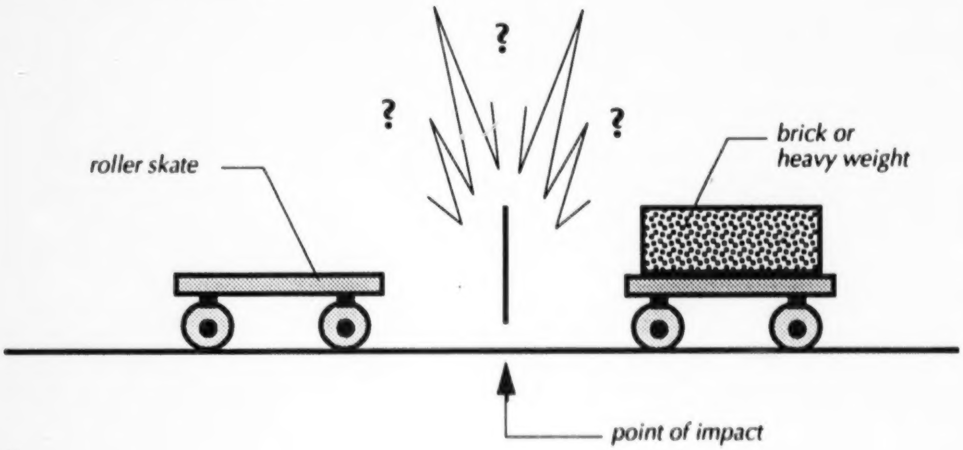
__How to explain it:__

This event demonstrates the **conservation of momentum.** If all the marbles are identical in mass and size, whatever number rolls against a row of stationary ones, the same number will move away from the stationary row. These last moving marbles are just taking over the momentum that the first marbles were imparting to the row of stationary marbles. **The momentum of a moving object is equal to the product of its mass and its velocity (mv)-** When this is imparted to another stationary object, this second object will have the same initial momentum ($m_1v_1 = m_2V_2$). When both objects have the same mass, the velocity of the second object (V_2) will be the same as the first object's velocity (v_1). When the moving ball is twice as heavy ($m_1 = 2m_2$), then two balls with masses m_2 will move away. A faster moving marble will impart the same speed to a marble of the same mass. A marble with half the mass of a stationary one will only impart half the speed to the heavy marble.

Applications of this principle are encountered in head-on collisions of trucks and cars, where the truck driver almost always survives the accident, but not the car passengers. This is because the truck has a much greater mass and thus only slows down on impact, whereas the small car bounces back or is crushed on impact.

3.2.24. THE CRASHING SKATES

What you need: 1. A pair of skates (boards on marbles or straws will also do).
2. A brick or other heavy weight.



How to do it:

1. Place a brick or other heavy weight on one of the skates.
2. Hold the two skates about a meter apart on a smooth surface (table or floor surface will do. Each skate can be held by two students at each end of the table).
3. Ask the students to push their skates toward each other with about the same speed on the count of three.

What to ask:

1. Which of the skates keeps moving in the same initial direction?
2. Which of the skates has a larger momentum?
3. If an egg were tied with a rubber band to each of the skates, which one do you think would most likely break?
4. What vehicles on the road can the skates be compared with?
5. In a head-on collision between a car and a truck, why does the truck driver usually survive the crash and not the car driver?

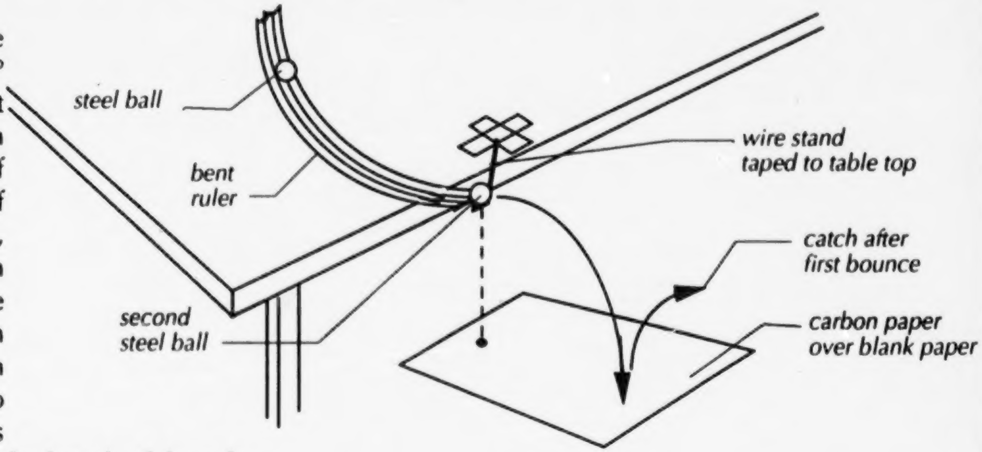
How to explain it:

The skate with the brick on top has a much larger mass and thus a much larger **momentum.** At the point of impact, the object with the larger momentum will keep on moving in the same direction, whereas the one with the smaller momentum suddenly has to reverse its direction of movement. This is the main reason why in a head-on collision of a truck and a car, the truck driver usually survives the crash. At the point of impact, the truck with a much larger mass than the car, keeps on moving forward, although with a much slower speed. The car, however, is suddenly pushed in a reverse direction and the people in this car are flung forward. The velocity of the people upon impact is the sum of the velocities of both vehicles. If for example the truck was driving 100 km/h and the car 90 km/h, at the point of impact, the people in the car would have a speed of 90 plus 100—it is like having a speed of 190 km/h hitting a brick wall, whereas the truck driver's speed would probably only be drastically reduced.

3.2.25. THE COLLIDING STEEL BALLS

What you need: 1. Two medium size steel balls (about 1 cm diameter).
2. A plastic ruler (30 cm long), metal washer. 3. Four sheets of carbon paper.
4. Rather stiff wire (coat hanger wire), masking tape .

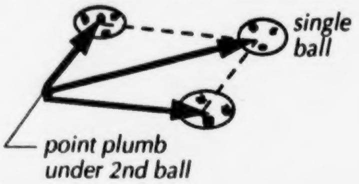
How to do it:



1. Make two 90° hooks at both ends of the stiff wire, such that the length from hook to hook is exactly the length of the ruler.
2. Bend the plastic ruler and keep it bent by hooking the wire behind the ruler and bending the wire with it (keep the center groove free).
3. Tape the end of the ruler to the table edge (by taping only the back and sides of the ruler and keeping the center groove free).
4. Make a small steel ball holder (stand) from a paper clip and tape this to the edge of the table, such that a steel ball can sit just off center in front of the groove (see sketch).
5. Hang a metal washer from a string attached to the paper clip stand and find the point plumb under the point of impact.
6. Tape four carbon sheets on top of four white sheets to the floor, such that the rolling steel balls will hit the paper.
7. Let a ball roll off the ruler 4-5 times and make sure that you catch it after the first bounce. Place a second steel ball on the stand in front of the groove and let the first ball collide into it, from the same height as when it was rolling by itself (catch both balls after their first bounce with the help of a student). Do this 4-5 times.
8. Take the sheets of carbon paper off and draw vectors (arrows) from the point of impact (plumb under the end of the ruler) to where the single ball fell and to where the two balls together bounced on the floor.

What to ask:

1. What is the relationship between the vectors?
2. What do the vectors indicate about the force or momentum imparted from the first ball onto the second steel ball?

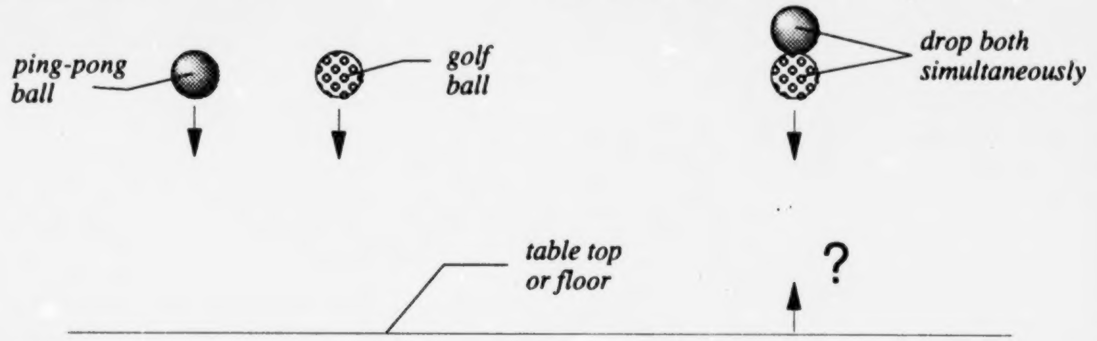


How to explain it:

The vector of the ball rolling alone, is like the resultant of the two smaller vectors of the 2 balls falling together (see sketch).

3.2.26. HOW HIGH WILL THE BALL BOUNCE ?

What you need: 1. One golf ball. 2. One ping-pong ball.



How to do it:

1. Hold the golf ball about waist high above a smooth hard floor or about half a meter above the table, and let it fall. Let students observe the height of the first bounce.
2. Do the same with the ping-pong ball and let the students again notice the height of the first bounce.
3. Now place the ping-pong ball on top of the golf ball and ask the students to predict how high the ping-pong ball will bounce up.
4. Drop the two balls simultaneously on the hard surface and observe!

(sometimes the ping-pong ball will shoot off in an angle; repeat until both balls fall vertically on top of each other).

5. Invert the order of the balls and ask: "What do you expect the balls to do now?" Drop the balls and observe!

What questions to ask:

1. What made the ping-pong ball bounce up so high?
2. Was the height of the bounce the sum of the heights of the separate balls bouncing? Was it higher than the sum?
3. Where did the ping-pong ball get its energy from, to bounce so high?
4. Why did the balls hardly bounce up when the golf ball was on top?
5. What would happen if we used a tennis ball instead of the golf ball?
6. How would the bounce of two ping-pong balls compare to our first bounce?

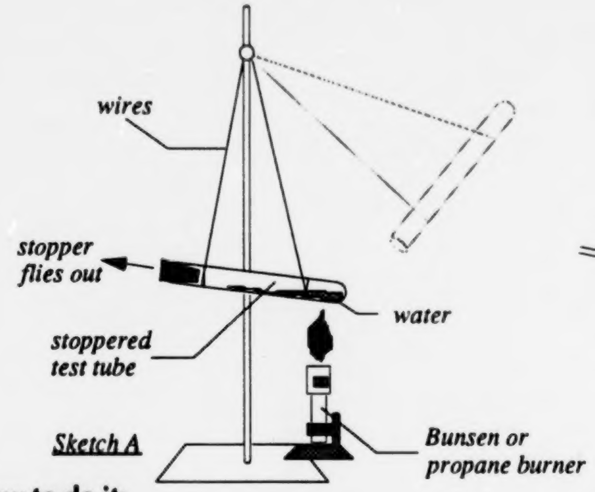
How to explain it:

The height of the bounce of each individual ball is about three quarters of the original height. When the ping-pong ball falls together with the golf ball (vertically underneath it), one would expect the bounce to be the sum of each ball individually making it twice as high, but it bounces up much higher. This is caused by the much larger mass of the golf ball as compared to the ping-pong ball. As the **momentum** (of the golf ball is **conserved**, it is actually imparted on the ping-pong ball : $(M_1v_1= M_2V_2)$. Because the mass of the ping-pong ball is much smaller, it has to have a much larger velocity (V_2) in order for the product of mass and velocity to stay the same.

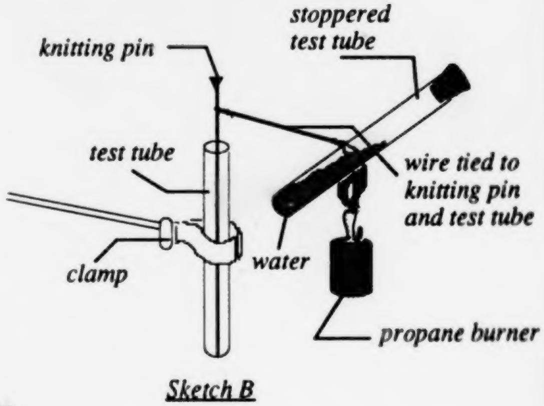
When the two balls are inverted, there is only a small momentum imparted on the golf ball after the bounce, which is not large enough to bounce the golf ball back, thus both balls fall dead on the surface.

3.2.27. THE TEST TUBE CANNON

What you need: 1. A thick walled test tube + cork or rubber stopper.
2. Tall stand, thin wire, Bunsen burner. 3. Protective goggles.



Sketch A



Sketch B

How to do it:

1. Tie two wires to the test tube and hang it from the tall stand as shown in Sketch A (somewhat slanted with opening up).
2. Pour a few ml of water in the tube and stopper with the cork or solid rubber stopper. **CAUTION:DO NOT INSERT STOPPER TOO TIGHTLY!!**
3. Put your safety goggles on and start heating the tube. Make sure that the mouth of the tube is facing away from people and breakable material.
4. Keep heating to boil the water - hold the burner with an outstretched arm and keep your face as far as possible from the tube, and wait for the POP! Observe the movement of the test tube!
5. An alternative way for suspending the test tube is shown in Sketch B.

What questions to ask:

1. What made the test tube move at the time of the "POP"?
2. How does the use of a rubber stopper compare to a cork?
3. Will the use of more or less water influence the amount of recoil?
4. How would a longer or wider test tube influence the recoil?
5. What is the danger in inserting the stopper too tightly?
6. Will the tightness of the stopper influence the amount of recoil?

How to explain it:

By boiling the water in the test tube, vapor is being created, and thus pressure is built up, as the test tube is stoppered tightly. The vapor molecules move faster and faster as energy is supplied to the steam by the heat, and at the moment that the pressure is high enough to overcome the friction of the stopper against the glass, the stopper POPS out.

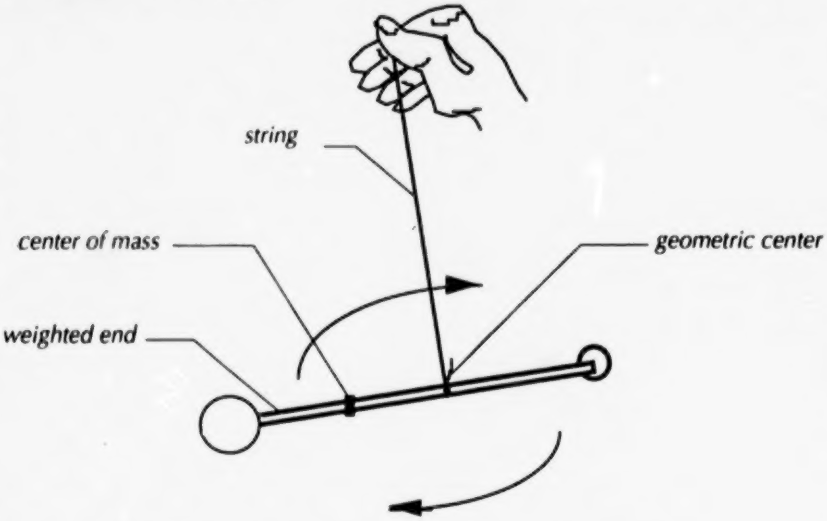
The heavier the mass of the stopper (rubber as compared to cork), **the larger the recoil distance,** as the momentum (M_1V_1) of the stopper is equal to the momentum of the test tube (M_2V_2) in which M = mass and V = velocity. When only M_1 is increased, and all other variables are held constant, it will result in an increase of V_2.

Using a wider test tube means increasing the stopper's mass, but also that of the test tube, thus the recoil would most likely stay the same. Using a longer test tube would change M_2 and thus the amount of recoil is not as large. This can be compared to using a revolver and a rifle (less recoil in a rifle, because of the increase of mass in using the rifle).

3.2.28. THE SPINNING PLANETS

What you need: 1. An aluminum or copper rod or tube (1 cm diameter, 50 cm long).
2. A large and a small styrofoam ball, string.

How to do it:



1. Stuff one end of the tube with the lead (solder wire or toothpaste tubes would do fine) and attach the larger ball to the weighted end and the smaller one to the other end of the tube.
2. Find the balance point of the tube and mark the center of gravity by drawing a line around the tube with a marker.
3. Tie the string to the geometric center of the tube and show that the tube cannot balance horizontally at that point. Ask: "How can I balance the tube horizontally from the string?"
4. Now spin the tube while holding the string with the other hand, and keep spinning the tube around (the tube is now hanging horizontally from the string). Observe the marked center of mass/gravity!

What to ask:

1. Did the geometric center stay in the middle of the rotating system?
2. Around what point did the system spin?
3. What kept the pipe hanging horizontally from the string?

How to explain it:

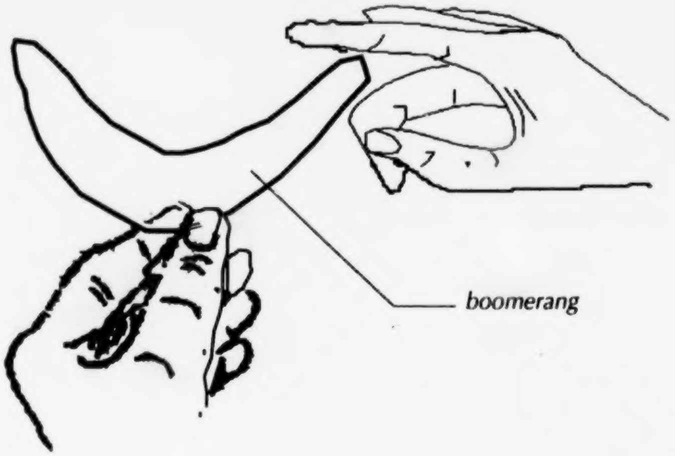
All **spinning objects spin around their center of mass**, and this is why the marked spot stayed at the same place while the tube was spun. The **geometric center**, not being the center of mass, because the tube was weighted at one end, had to spin around the center of mass. This is the reason why we could keep the tube spinning. As the tube was spinning in a horizontal plane, it was actually kept horizontal and hanging horizontally from the string, even though it was not hanging from its center of balance (center of mass/gravity). The **plane of rotation** of the tube happened to be in a horizontal plane. If the tube could be spun at a higher speed, this plane of rotation could take up any position.

These two spheres could be likened to two planets in space moving around each other, the smaller one rotating around the larger one, with the center of gravity of the system as the center of rotation.

3.2.29. THE PAPER CARD BOOMERANG

What you need: 1. A stiff paper card (5x8" / 12x20 cm). 2. A pair of scissors.

How to do it:



1. Cut the paper card in the shape of a boomerang with a pair of scissors (see sketch).
2. Hold the paper boomerang with two fingertips at the bend, and slightly turn the legs upwards (by stroking them).
3. Hold the boomerang at an angle of 45° very lightly between index finger and thumb of your left hand, and flick it away with the middle finger of the right hand (see sketch).

What to ask:

1. What made the boomerang return by itself?
2. What is most essential for a boomerang to be able to return?
3. If the paper boomerang were not spun, would it return?
4. Why does the boomerang have to be thrown slightly upwards?
5. Would other shapes work to make a boomerang?

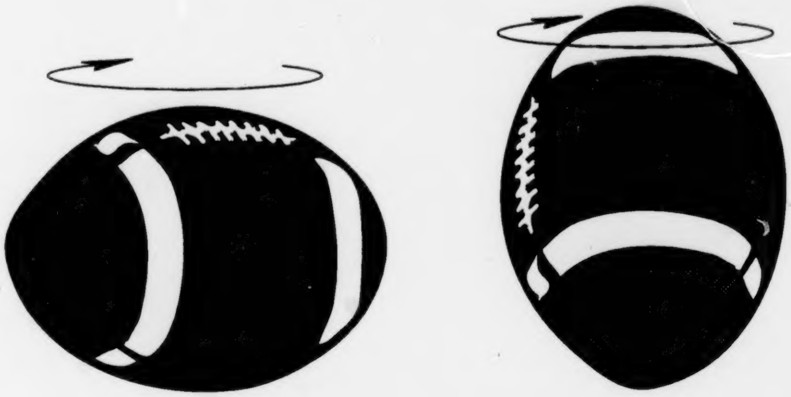
How to explain it:

When we flick the boomerang, a double movement is imparted to it: a spinning or fast rotation and a general upward motion. The spinning forces it to rise obliquely and **conserve its angular momentum in the plane of rotation** until the general upward momentum is exhausted. At this point it is still spinning, but instead of rising further, its weight causes it to descend. However, it does not drop straight down, but as **it tends to conserve its angular momentum** and also its plane of rotation, it slides back to the thrower in almost the same plane. The air resistance helps the boomerang to stay in its plane of rotation and it actually rides on the air, returning to the man who threw it in the first place.

"Frisbees" may be thrown like a boomerang based on this same principle, when a partner for a catcher is not available.

3.2.30. THE SPINNING FOOTBALL

What you need: 1. An American football (actual or toy size). 2. A smooth table top.



How to do it:

1. Place the football horizontally on the table top.
2. Hold it down firmly with the fingers of one hand and give it a quick spin. Observe! (If nothing happens, it was not spinning fast enough: try again).
3. Instead of a football, a hard-boiled egg may be used and it will behave the same way.

What questions to ask:

1. What did you observe the ball doing?
2. What made the football spin vertically?
3. What would happen if you spin the football slowly (horizontally)?
4. What would happen if you spin the ball vertically?
5. Why doesn't the football stay spinning vertically?
6. What would happen if you spin the football fast vertically?
7. Why can't you spin the football fast horizontally and keep the ball spinning horizontally?

How to explain it:

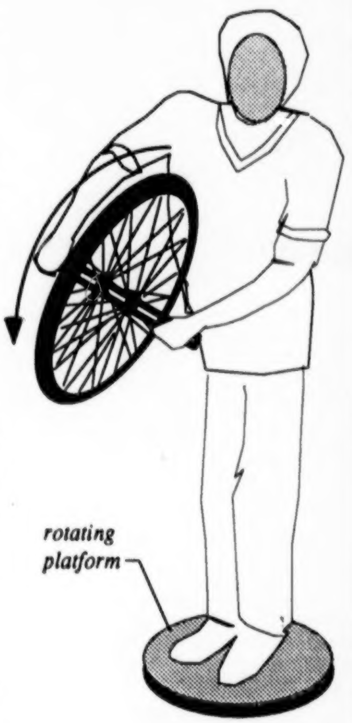
It takes more energy to rotate or spin the football horizontally as compared to vertically. This is because the mass of the football is spread out further from the center of gravity which is also the **center of rotation,** when it is in the horizontal position. There is a tendency for a system to move toward a **state of lowest internal energy** or **enthalpy,** which is the case when the football moves from the horizontal to the vertical position. But in order to spin at this position a certain **energy level** is required. This is why a slow spin at the horizontal position will just keep it spinning horizontally.

We find this principle applied in our daily life in figure skating, where the skater will spin faster when he/she pulls in his/her arms closer to the body while spinning. **(Conservation of Angular Momentum).**

During the high dive in the swimming sport, we see that divers keep their body closely tucked in when doing forward or backward saltos or flips. When they want to slow down the rotation, they stretch their body and this usually happens just before they enter the water.

3.2.31. THE HUMAN GYROSCOPE

What you need: 1. An old bicycle wheel.
2. A wooden board (about 50 x50 cm), an old broom stick.
3. A hand full of steel ball bearings.

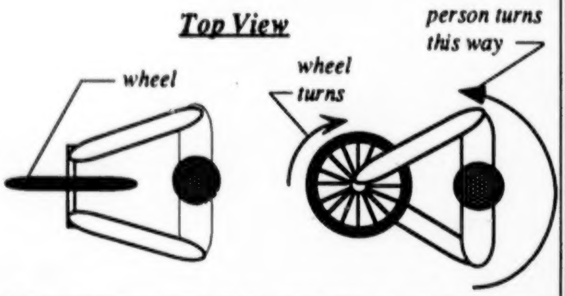


How to do it:

1. Cut a couple of pieces of broom handle and attach them to the axle on each side of the bicycle wheel for handles (drill holes in one end of the wood and screw the wood in the axle end).
2. Place the wooden board on the ball bearings on a smooth floor surface and have someone stand on the board.
3. Hand the wheel to the person standing on the board and let him/her hold the wheel vertically while you spin it with a downward motion.
4. Now ask the person holding the spinning wheel to rotate the plane of rotation from the vertical position to a horizontal position by turning it to the left. (What happens to the person?)
5. Now ask him/her to bring it back to the vertical position and keep turning it to the right to a horizontal position (What happens now?).

What questions to ask:

1. Which way did the person holding the wheel turn, clockwise or counterclockwise (top view) when turning the spinning wheel to the left?
2. After turning the wheel to the left, in what direction does the wheel spin? Clockwise or counterclockwise? (looking from the top).
3. After bringing the wheel back to its original vertical position, what happened to the person holding the spinning wheel?
4. In which directions did the wheel and person rotate by turning the spinning wheel to the right?



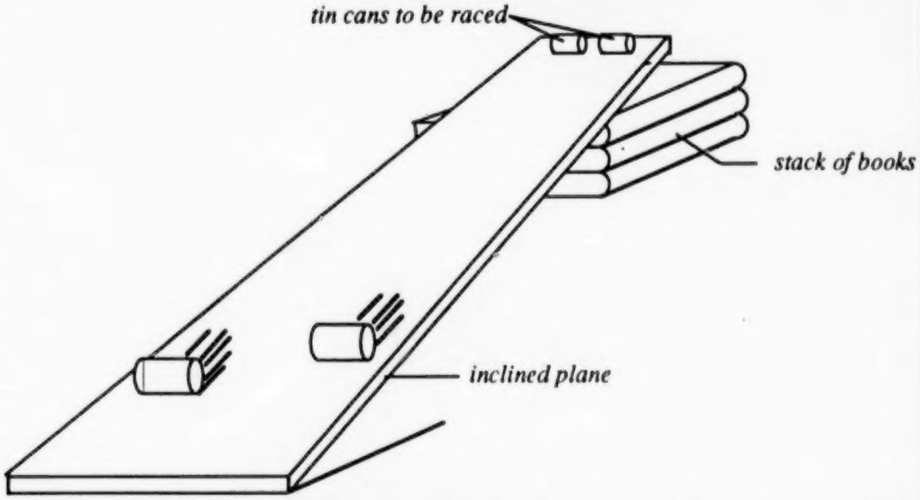
How to explain it:

By turning the spinning wheel to the left, the wheel was turning in a clockwise direction and the person on the platform rotated counterclockwise : **conservation of angular momentum.** The faster the wheel spins and also the more mass the wheel has (attaching lead weights to the wheel rim would be effective), the greater the angular momentum; thus the more difficult to turn the **plane of rotation** (flywheels in ships). The turning to the left of the person when the wheel is tipped to the left is called **precession.** This occurs f.i. in motorcycle riding: in order to turn left the motorcyclist tips the vehicle to the left and almost doesn't have to move his steering. A right turn is made by tipping the vehicle to the right.

3.2.32. THE TIN CAN RACE

What you need: 1. A variety of round tin cans of soup, vegetables, fruit cocktail, tomato juice, including solid dog food. 2. A stop watch (optional).
3. A one meter long inclined plane (a wooden board propped up at one end with a stack of books).

How to do it:



1. Set up the board as in the Sketch to form the inclined plane.
2. Divide the class in groups of at least three students in each group: one student to release the cans at the top of the plane, one to catch the cans at the bottom end of the plane, and one to record the time or to observe which of the two cans won the race.
3. Let each group of students choose a tin can that they think should roll the inclined plane the fastest and be the winning can (take average of three).
4. Let two groups at a time race their tin can against each other. The winner of this race will compete against the next group, etc. until all groups have participated. Declare the overall winner!

What questions to ask:

1. Which of the tin cans is the overall winner?
2. What is the consistency of the contents of the winning can?
3. How did the tomato soup compare to the chunky soup?
4. How did the larger tin cans compare to the smaller ones?
5. Were the heavier cans always winning from the lighter ones?
6. What are the variables involved in determining the rolling speed?
7. Which are the manipulated and responding variables?
8. How can we control the other variables?

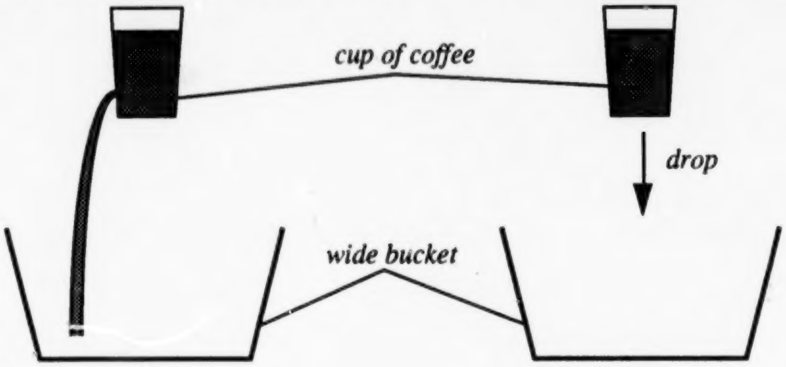
How to explain it:

The variables involved in the tin can race are: rolling speed (responding), size, contents, weight of can, incline of the plane, etc. Any of the latter variables can be the manipulated one. Say we wanted to manipulate the size of the can, then we take two different sizes of cans containing the same thing. If we take, f.i. a can of soup and the solid dog food (with the same size), then we are manipulating the contents (in this case the consistency). Invariably, the can with the solid contents will win the race, as the **moment of inertia** is the smallest to overcome. Cans containing loose chunks of mass, like chunky soup or fruit cocktail are most likely the slowest, as they have the tendency to get the mass on the periphery of the can and thus the highest moment of inertia. (Hollow and solid cylinders can also be used to compare rolling speed).

3.2.33. THE CUP OF COFFEE DROP

What you need:

1. A styrofoam cup, a large wide and deep bucket. 2. Coffee or intensely colored water.



How to do it:

1. With a pencil point poke a hole near the bottom in the side of the foam cup. Place a finger over it and fill the cup with coffee or colored water (if colored water is used, make sure it is intensely colored).
2. Stand and hold the liquid-filled cup over the bucket, which is placed on the floor in front of you. Let go of your finger over the hole and show that the liquid squirts out of the cup.
3. Place your finger back over the hole and tell students that you are going to drop the whole cup. Let them follow the falling cup and observe closely whether any liquid is squirting out of the hole while the cup is falling. Now drop the cup and simultaneously remove your finger which was covering the hole.

What questions to ask:

1. What makes the liquid squirt out of the hole in the beginning?
2. Would the strength of the squirt be the same on the surface of the moon, all other variables being equal?
3. Why did the liquid stop squirting during the fall?
4. What would happen if the finger covering the hole is removed a little sooner than the release of the cup?
5. If this same liquid-filled cup is held in an orbiting satellite, would any liquid squirt out of the hole? Would it be possible to hold the liquid in an open cup?

How to explain it:

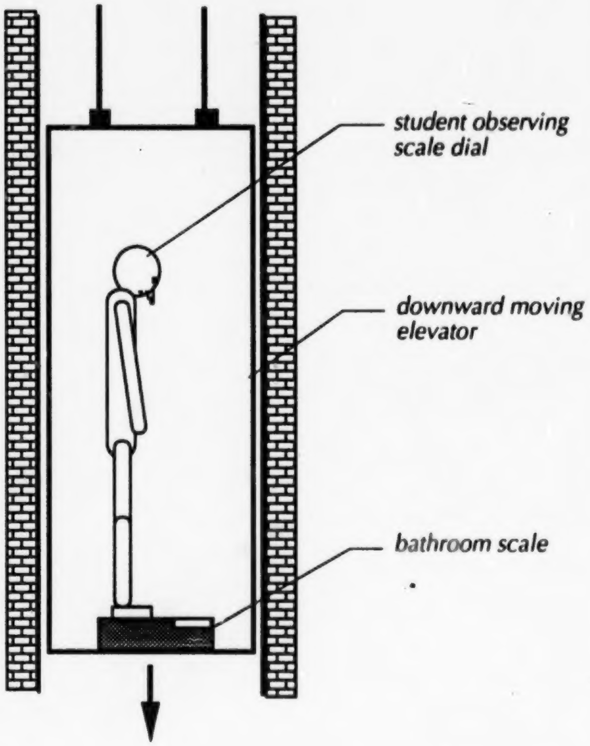
When the liquid-filled cup is held stationary, the liquid is pulled down by the earth's **gravity** causing a **liquid pressure** at the point of the opening in the side of the cup, resulting in the squirt. When the cup is falling, the liquid pressure is suddenly eliminated, and no liquid is squirting out.

All variables being equal, when this liquid-filled cup is held on the surface of the moon, the liquid will only squirt about one sixth of the distance from what it was on the earth, as the gravity pull is about 1/6th of the earth's.

In a space satellite, no liquid will come out of the hole at all, just like in the falling cup, all materials actually are weightless. It would be very difficult to keep liquids in an open container in a satellite, this is why liquids are always stored in plastic bags.

3.2.34. THE FALLING ELEVATOR

What you need: 1. A bathroom scale. 2. A fast moving elevator.



How to do it:

1. Take the students in small groups or individually into a fast moving elevator.
2. Let one student stand on the scale in the center of the elevator and have the other students observe the indicator of the scale.
3. Send the elevator up and down, and draw attention to the weight change at the start and end of the upward or downward motion.

What to ask:

1. What did the scale indicate at the start of the upward motion?
2. What was your weight at the beginning of the downward motion?
3. How do you usually tell, without looking at the lights (indicators), which direction the elevator takes you?
4. What would happen to your weight if the elevator were to fall freely?
5. What is it that causes things to have weight?
6. Does weightlessness have any effect on the mass of objects?

How to explain it:

It is the **attraction** of objects **by the earth** that gives them their weight. This weight is measured by the deflecting needle of a scale, usually based on the degree of stretch in a spring. In the motionless elevator, the weight of the student is the same as that on the solid floor. But, as soon as the elevator starts its upward motion, an **added force** upward is exerted on the scale, which increases the student's weight. This force, however, is only exerted during the accelerated part of the upward motion.

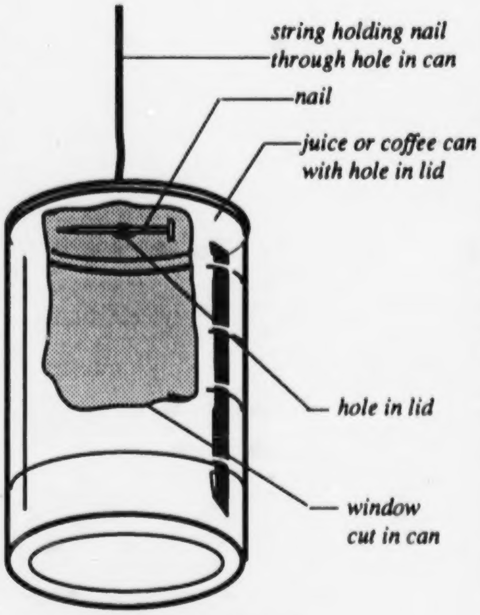
When the elevator moves down, a downward force is exerted, resulting in a smaller upward force on the scale, and thus showing a lower weight. If the elevator were to fall freely, a **constant acceleration** and thus a force downward is exerted on the scale, eliminating the upward reactive force of the student's weight, resulting in weightlessness of the person.

3.2.35. THE WEIGHTLESS NAIL

What you need: 1. A coffee can plus lid. 2. A nail and thin string.

How to do it:

1. Make a small hole in the center of the coffee can lid.
2. Tie the nail to one end of the string (about .5m) and run the other end through the hole in the coffee can lid.
3. While holding this end of the string, place the lid on the can.
4. Place the can on the table; hold the nail by the string and let go of the string: **CLICK!**
5. Now pick up the can and the nail by the string and hold them about 1 m (3 ft) above the floor or the table top.
6. Let students listen closely, and let go of the string: **CLICK - CLICK!**


string holding nail through hole in can
nail
juice or coffee can with hole in lid
hole in lid
window cut in can

Looking up on can

What questions to ask:

1. What made the first click? And the second click?
2. Where was the nail during the falling of the can?
3. In relation to the can, did the nail have any weight?
4. What other objects could we use in place of the nail?
5. When do we experience an almost weightless situation of our own body?
6. In a capsule that orbits around the earth, what can we compare to the can and the nail?
7. Would the two clicks always occur at the same time one after the other?
8. What characteristic of the tied object should be changed to make the span between clicks longer? And what property of the can itself?

How to explain it:

When coffee can and nail were released at the same time, they were falling at the same rate (disregarding the air resistance against the can). During this time, therefore, no sound was heard until the can hit the floor - first **CLICK.** The nail was still falling then and at the moment it hit the bottom of the can we heard the second **CLICK.**

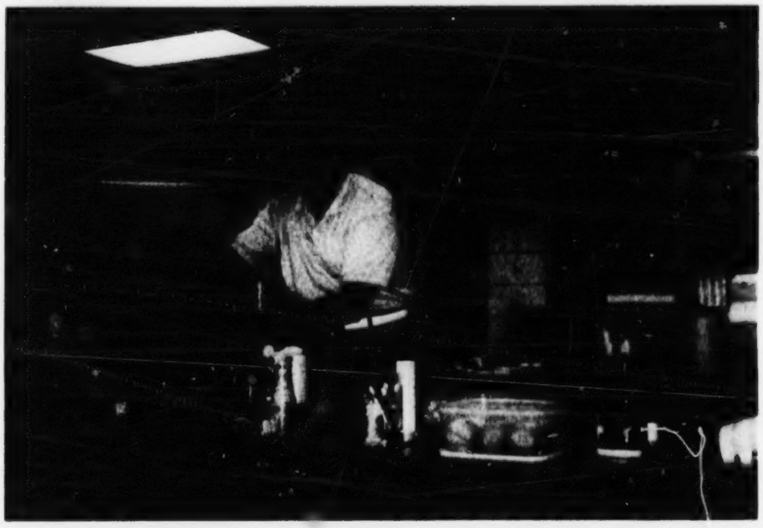
The time span between the two clicks can be lengthened **only** when a longer can is used (dis regarding air friction). This will make the falling distance of the object longer and thus it increasing the falling time. Changing the weight of the falling object inside the can has no influence upon the rate of falling, since this rate is the same for all falling objects. When we take air friction of the falling object inside the can into consideration, a wider and flatter object would probably fall slower inside the can, and thus lengthen the time span between the two clicks.

This falling coffee can and the nail inside it may be compared with a capsule orbitting the earth and the people inside the capsule respectively. Since the capsule is constantly falling - **continuous free fall** and the people inside the capsule are falling with the same rate, the people inside the capsule experience weightlessness. Meaning that in relation to the capsule they are weightless. Actually all objects inside the capsule are weightless, but maintain their masses.

We can experience some weightlessness at certain rides in fairs: for example in the "Falling Drum" or the roller coaster, at the moment that the drum or car that's holding us almost falls freely. This we experience to a lesser extent in fast moving elevators. The sudden acceleration in good elevators are very much cushioned or more gradual, so that the rides become much smoother.

To Be Believed and To Gain Respect

NEVER PREACH
WHAT YOU DON'T PRACTICE



THE INVERTED GLASS OF WATER

Will this work on the surface of the moon?
Or in an earth orbiting capsule?

CHAPTER 3

WHAT ARE SOME PHENOMENA OF THE EARTH AND THE MOON ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

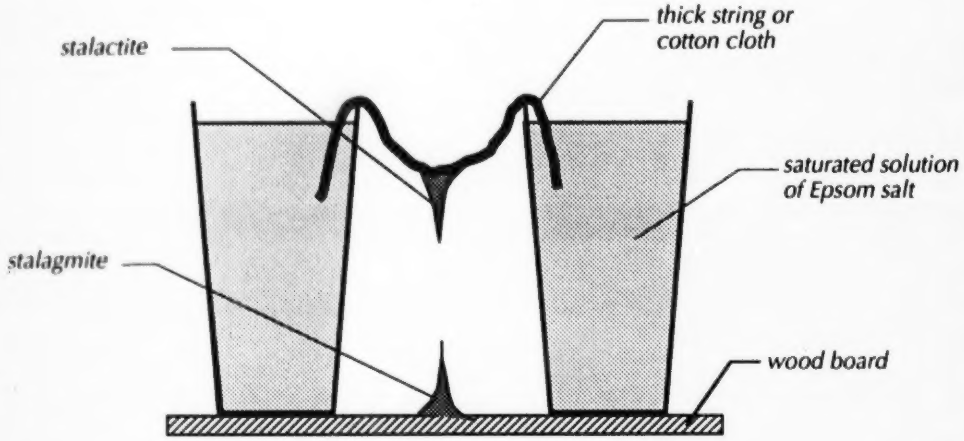
a. Recognize the correct explanation of an observed event based on each of the sub-concepts;
b. Explain in their own words which of the sub-concepts is determining the course of an event;
c. Distinguish true from false statements concerning each one of the sub-concepts;
d. Identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

— Dissolved salts in ground water are deposited when the water evaporates, as in stalactite and stalagmite formation.
— Some rocks are softer and more soluble in dilute acids than others.
— Erosion and weathering may occur by plant growth or the freezing of water.
— Continents and ocean floors stay at the same level in spite of erosion and deposits of material, because of the liquid mass in the inner core of the earth (isostatics).
— Volcanic and geyser eruptions are caused by pressures in deeper lying layers of the earth.
— The phases of the moon are caused by the different positions of the moon in relation to the earth and to the sun.
— A solar eclipse is caused by the moon's shadow on the earth.

3.3.01. MAKE STALACTITES & STALAGMITES

What you need: 1. Magnesium sulfate (Epsom salt). 2. A large beaker and stirrer.
3. Two small beakers, a thick water-absorbent string or cloth.


stalactite
thick string or cotton cloth
saturated solution of Epsom salt
stalagmite
wood board

How to do it

1. Make a saturated solution of magnesium sulfate in water in the large beaker, by dissolving as much of the powder as you can in about 200 ml of water (until some solid stays undissolved).
2. Fill the two small beakers with the saturated solution and place a thick water-absorbent string or cloth between the two beakers, such that the center part hangs somewhat lower than the beaker's rim (see sketch above).
3. Let stand for a few days and observe.

What to ask:

1. Which cone is called stalactite and which stalagmite?
2. How were the cones formed?
3. What material are the stalactite and stalagmite made up of?
4. What other materials can we use instead of the string or cloth?
5. Where in nature are stalactites and stalagmites formed?

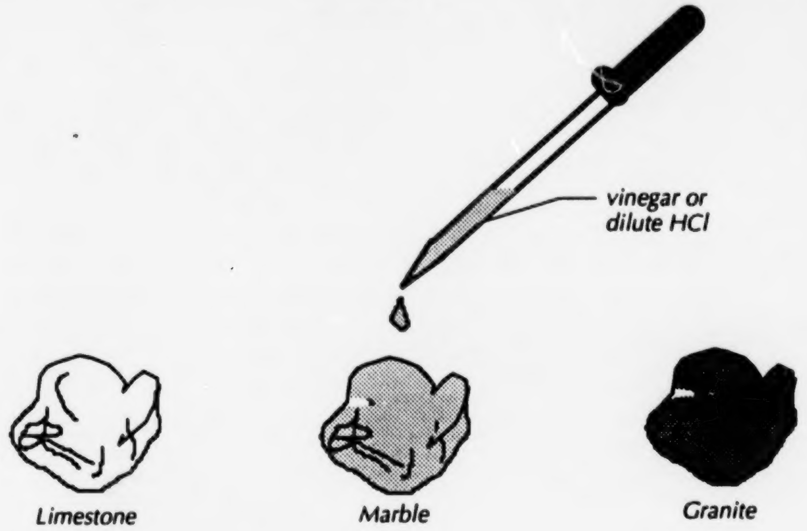
How to explain it:

Stalactites and stalagmites in nature may be found in **underground caves.** Groundwater which contains **dissolved salts and minerals**, drips from the ceiling of the cave. While the drop hangs down, the water evaporates and leaves some of the salts deposited on the ceiling, forming the **stalactites**. Similarly, the **stalagmites** are formed on the bottom of the cave. The water drops containing the dissolved salts evaporate and keep depositing the salts on the same spot, leaving a cone of salts that were dissolved in the water.

This demonstration is a simulation of the stalactite and stalagmite formation in caves, which may have taken centuries to build up. Water-absorbent paper towel, blotting paper, etc. may be used instead of the string or cloth.

3.3.02. CAN STONES DISSOLVE ?

What you need: 1. Pieces of limestone, marble, granite. 2. Vinegar or dilute hydrochloric acid.



How to do it:

1. Observe the pieces of limestone, marble, and granite. Ask: "How do they differ? How do we know which is which?"
2. Place a few drops of vinegar or dilute HCl on a flat surface of each of the rocks and observe for chemical reaction.
3. Let stand for a few minutes, then place again a few drops of acid on each of the rocks. Ask: "Which one reacted most?"
4. Scratch the surface of each of the stones with the fingernail or a pen knife. Ask: "Which one is the softest? Which the hardest?"

What to ask:

1. How can we distinguish which stone is which?
2. What are the characteristics of each of the stones?
3. Which of the stones would be eroded most when subjected to the same erosive forces in nature?
4. How would you tell the difference between common salt and marble?
5. What other methods are geologists using to identify minerals?

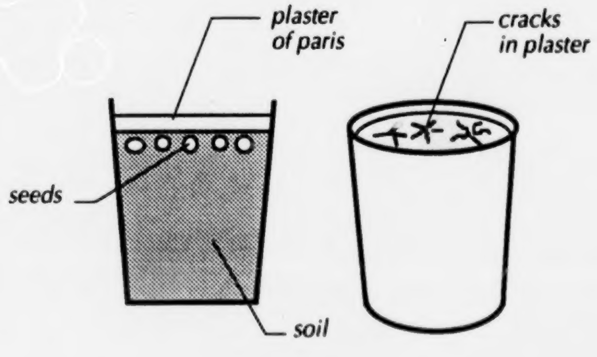
How to explain it:

The limestone is the softest of the three and granite the hardest. Limestone can most likely be scratched by the human fingernail (number 4 in the **hardness scale**), whereas the other two cannot. Limestone reacts most with the vinegar or dilute hydrochloric acid. Marble does react with the acid, but not as readily, because of its more compact structure. Chemically they are the same (calcium carbonate).

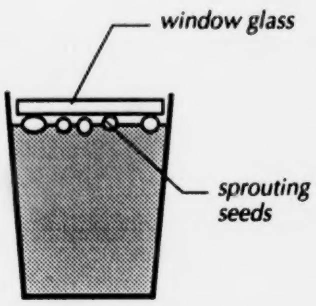
Other methods that geologists use to identify minerals are: breaking the rock and observing the crystal structure with magnifying glasses or microscopes.

3.3.03. CAN PLANTS BREAK ROCKS ?

What you need: 1. Dried lima beans, red beans, or corn seeds. 2. Two small flowerpots & soil.
3. Plaster of Paris (or 'Polyfilla'). 4. A piece of window glass (the size of the pot).



Pot 1



Pot 2

How to do it:

1. Soak six to ten beans or seeds in water and let stand overnight.
2. Plant the seeds just under the soil surface in the pot, and water.
3. Cover the soil with 1 cm thick layer of plaster of Paris (or Polyfilla); cover the other pot (with planted seeds) with window glass.
4. Observe and examine the two pots daily (in pot 1, cracks will appear in the plaster; in pot 2, the glass will be lifted).

What to ask:

1. Why did the seeds have to be soaked before planting?
2. What happened to the plaster of Paris after a few days?
3. What did you observe the window glass was doing after a few days?
4. Can we find places where plants have broken through asphalt, brick or cement?
5. If sprouting seeds have such strength, can you imagine how strong the roots of tall trees are?

How to explain it:

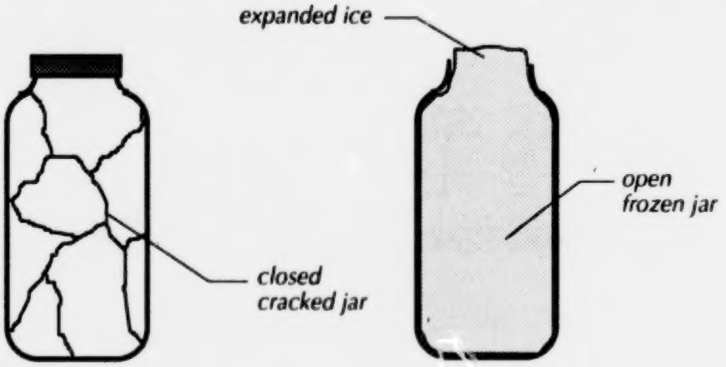
This demonstration may be used as an activity for students to discover the strength of sprouting seeds, and how they can cause rocks to move out of their path of growth or break them up into smaller pieces.

Take the students out on the school yard (or the neighborhood park) to find plants that have grown through cracks in the sidewalk, lower edges of the wall, or other such places.

Roots of tall trees can easily break foundations of concrete when the trees are planted too close to the buildings. Large rocks can similarly be broken up by the growth of roots, causing **pulverization or erosion** of the rocks.

3.3.04. HOW CAN WATER BREAK ROCKS ?

What you need: 1. Two empty jars (one with a screw lid).
2. A piece of sandstone, limestone, and pumice.
3. Four small polyethylene bags.



How to do it:

1. Fill the two jars brimful with water.
2. Close one off with the screw lid, leave the other open, and place both jars in the freezer, after wrapping them in a plastic bag.
3. Observe what happened to the jars after three or four hours, or at the end of the day.
4. Soak the pieces of rock in water and place them in the freezer, after each one is wrapped in a plastic bag.
5. Observe what happened to the rocks at the end of the day.

What to ask:

1. What happened to the two jars with water after the water froze?
2. Would the closed jar also break if it was not completely filled?
3. How much air space do we need above the water in order for the jar not to break in the freezer?
4. How similar is this breaking of the filled and closed jar in the freezer to the breaking up of rocks in nature?
5. In what regions of the world does this process of erosion occur?

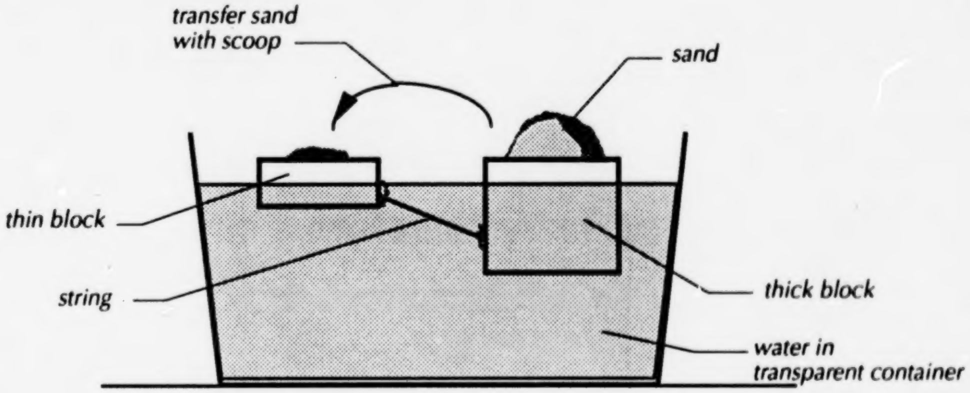
How to explain it:

The jar that was closed off broke into pieces after the water froze. This happens because **water expands when it changes into ice.** This freezing action is so strong, that it can break basement walls when the drainage outside the basement is not adequate.

Similarly, when water seeps into cracks or pores of rock, especially of pumice, and the temperature drops below freezing, the water freezes, expands and breaks up the rock. This type of erosion only occurs in regions of the world where temperatures drop below 0° C in winter.

3.3.05. WHY DO ERODED MOUNTAINS KEEP RISING ?

What you need: 1. A thin and a thick block of wood.
2. Sand and a scoop, a short piece of string.
3. A transparent plastic container (or aquarium).



How to do it:

1. Tie two short pieces of string to the wooden blocks in such a way that about 10 cm is separating the pieces of wood.
2. Fill the large container with water and let the two wooden blocks float on the water surface.
3. Place a heap of sand on the thick block, such that it just floats above the surface of the water.
4. Transfer the sand little by little to the thin block with the scoop. Observe the rising and sinking of each block.

What to ask:

1. What do the two blocks represent?
2. How was the erosion of the mountain simulated?
3. How was the total height of the mountain affected by the transfer of the sand?
4. Why does the ocean floor stay relatively stable in depth?

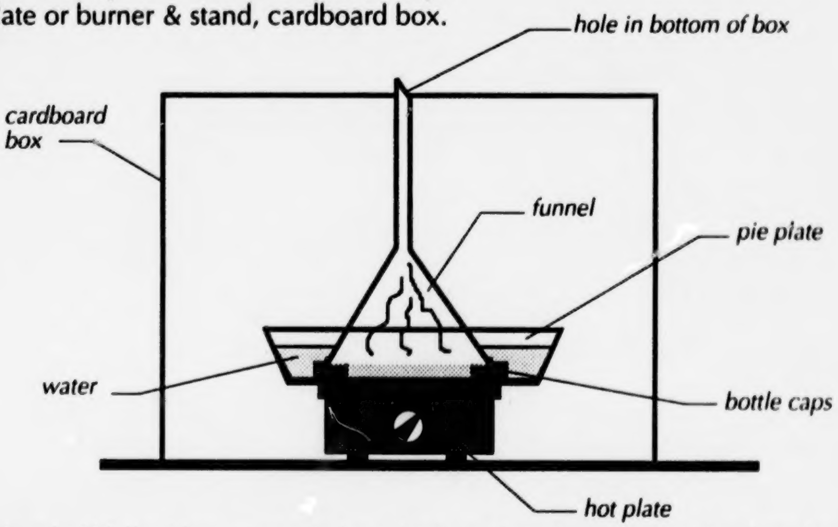
How to explain it:

The thick block of wood and the sand on top of it represents land with a mountain on it. The rain water and the weathering **erodes** the mountain and transports the eroded material to the ocean floor: represented by the thin block of wood. The **erosion process** is simulated by the moving of the sand with the scoop. The total height of the mountain above the water surface stays about the same, even after taking some sand off, because the block gets lighter and floats higher above the water surface.

Similarly, the ocean floor (thin block) does not get much higher relative to the water surface, as it becomes heavier and thus floats lower.

3.3.06. HOW DOES A GEYSER WORK ?

What you need: 1. A pyrex or aluminum pie plate.
2. A medium size Pyrex funnel, three bottle caps.
3. A hot plate or burner & stand, cardboard box.



How to do it:

1. Fill the pie plate half full with water and place the funnel on it, resting on the three bottle caps.
2. Place the pie plate on the hot plate or over the burner (see sketch).
3. Heat the water in the pie plate until boiling. Make a hole in the bottom of the box, cover the whole set-up with it and let the funnel stem protrude through the hole. Observe geyser action!

What to ask:

1. What did the water do when it was heated?
2. What made the water spurt out of the funnel?
3. What can we compare the cardboard surface to?
4. Why does the hot water inside the earth escape to the surface?
5. What will happen when the heat is turned off?
6. How can we let the geyser erupt again?
7. How similar is volcanic action compared to geyser action?

How to explain it:

By heating the water, it expands. At the moment that it boils, water vapor is formed, **pressure** is built up under the funnel and this force pushes the water out of the funnel. When the heat is taken away, the water cools down and the eruptions stop. In order to start the geyser to erupt again, the water needs to be heated to boiling.

This demonstration illustrates clearly the similar working of the hot water under the earth's surface, the **build-up of pressure**, and the release of the water through small cracks in the earth's surface: called the **Geyser.** Volcanic action is quite similar except that instead of water, we have molten lava, which comes out of the mouths of volcanoes.

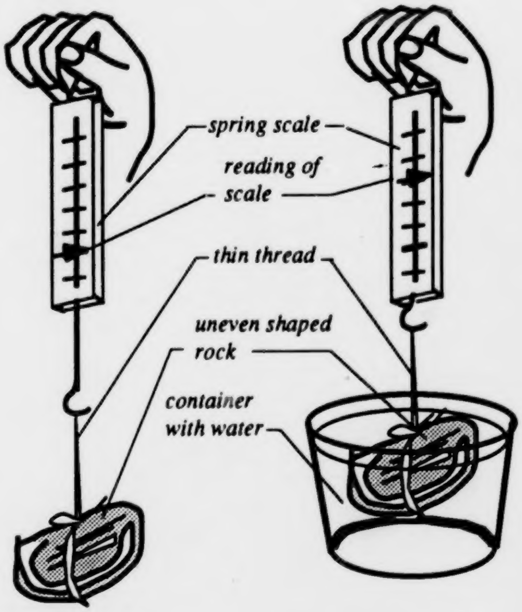
To make it inquiry oriented, conceal the set-up and let students find out the reason why the water spurts out.

3.3.07. WHAT IS THE ROCK'S S.G.?

What you need: 1. A small spring scale (one that can be hand held).
2. A container for water (large enough to contain the whole rock)
3. An irregular shaped rock. 4 Thin string.

How to do it:

1. Tie the rock on the end of the string and hang it from the spring scale (see Sketch A).
2. Read off how much it weighs and make a note of it. (reading A)
3. Fill the container with water, such that the whole rock can be immersed in the water.
4. Hang the rock from the scale and plunge it in the water (see Sketch B).
5. Read off how much it weighs now and make a note of it. (reading B)
6. Subtract reading B from A, and divide this difference into reading A.
7. The specific gravity or density is expressed in grams (mass units) over cubic centimeters (volume units).



Sketch A ***Sketch B***

What questions to ask:

1. Which of the two readings was greater?
2. Did the water level in the container go up or down after immersing the rock in the water?
3. In what ways can we measure this increase in water volume?
4. What property of the rock is this volume difference of water equal to?
5. Would two different types of rocks with the same mass displace the same amount of water?
6. Would two rocks which displaced the same amount of water have to be of the same type?
7. What other properties do we have to look at besides the *specific gravity,* to determine whether rocks are exactly of the same type or not?

How to explain it:

Since the difference in weight of the rock in air and immersed under water is equal to the upwards force or **boyancy force,** it is also equal to the displaced water volume or weight (since the density of water is 1). This displaced water can be measured in a graduated measuring cylinder or in an over flow can (see Event 15.7 ISI-2nd Ed). This volume is important, because it is exactly equal to the volume of the rock itself. As the mass of the rock is know from the first weighing (reading A) and the volume of the rock is calculated from the difference of the two weighings (reading A - reading B), the **specific gravity** or **density** of the rock can be calculated from A/(A-B).

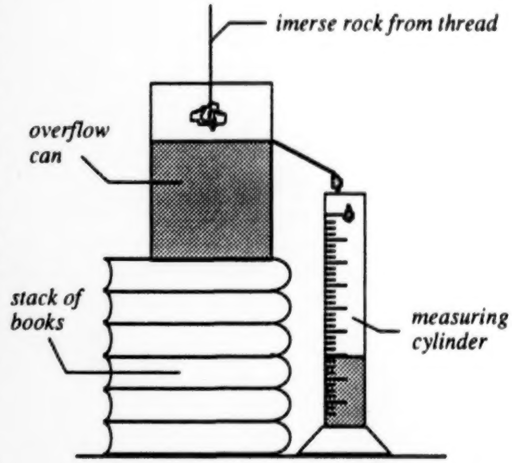
Different rocks of different types would have different specific gravities. This is only oneproperty of rocks that we would look at in order to determine whether the rocks are of the same type. The more obvious properties of rocks are of course their color and hardness. This last property is usually checked by scratching the rock with the human nail (No 4 of the hardness scale: from 1, softest, Talcum to 10, hardest, Diamond). Another property is the crystalline structure, usually quickly checked by breaking the rock and examining the cleavage.

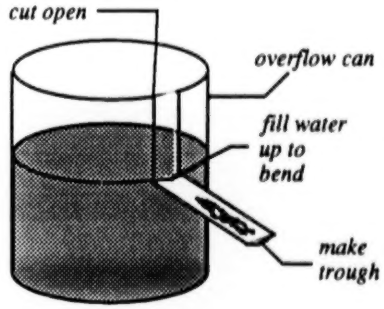
3.3.08. HOW CAN WE DETERMINE THE ROCK'S VOLUME?

What you need: 1. A medium size tin can. 2. A measuring cylinder, a piece of thread.
3. Different rocks, including: pumice, sandstone, granite.

How to do it:

1. Make an overflow can by cutting a 2 cm vertical strip of about 5 cm long out of the side of the can and bend this strip outward, making a small gutter out of the strip by bending the outer edges up (see Sketch).





2. Place this overflow can on a stack of books and fill it with water until the water just overflows.
3. Place the measuring cylinder underneath the end of the overflow trough to catch the overflowing water.
4. Tie the rock to be measured to a string and lower it slowly into the overflow can until it is completely submerged. Read off the volume of the water in the cylinder (for floating objects, like pumice, use a needle to immerse the whole object underneath the surface of the water).
5. Weigh each of the rocks on a scale and let students determine the densities of each of the rocks (D = M / V).

What questions to ask:

1. What made the water overflow?
2. What influences the amount of water overflowing?
3. Why does the pumice stone have to be pushed under water?
4. What result would we get if the pumice was not completely submerged?
5. What are the variables to be controlled if we wanted to compare the water displaced by the different rocks?
6. Does the shape of the rocks influence the amount of overflow?
7. Would a round and a cubical rock of the same type and weight (mass) have different amounts of overflow?

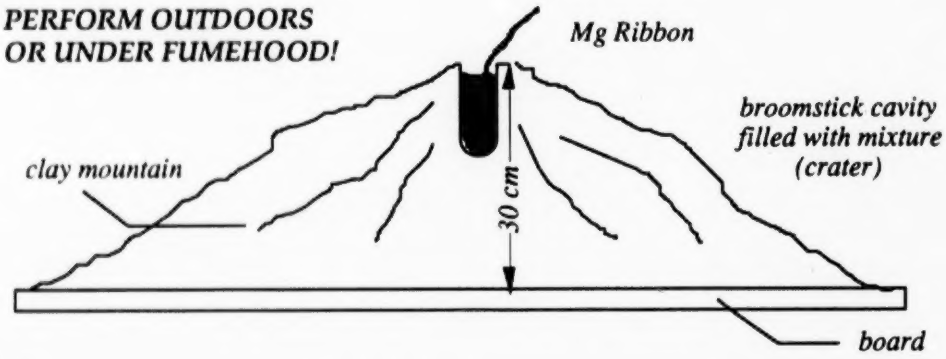
How to explain it: The different types of rocks have different densities, and as **density is defined as being mass of the object per unit of volume,** it is necessary to determine the volume and the mass of each of the rocks. The volume of an odd shaped object (which rocks usually are) can easily be determined by submerging it in water and measuring the displaced water. This can be done with the overflow can. When rocks of the same weight but of different types are submerged in the overflow can, different volumes of displaced water will be obtained. This is caused by the different densities of the rocks. The amount of overflow for the same type of rock will be the same, as long as the mass of the rock is held constant (the same), no matter what shape it is in.

3.3.09. SIMULATE A VOLCANO ERUPTION

What you need: 1. Ordinary earth clay & a wooden board (about lm x lm).
2. Ammonium bichromate (50 g), magnesium powder (12 g).
3. Magnesium ribbon (about 1 m long). 4. A wooden broom stick.

CAUTION:

PERFORM OUTDOORS OR UNDER FUMEHOOD!



How to do it:

1. With the wood board as a base, have the students build a volcanic cone with the clay of about 30 cm high and a diameter of 60 cm at the base. Push the handle of a broom in the middle of the volcano down to about 6 cm deep to form the crater
2. The 50 g ammonium bichromate is enough for about 3-4 eruptions. Mix about one third of the amount of bichromate with about 4 g of magnesium powder and pour the mixture in the crater.
3. Cut a 10 cm strip of magnesium ribbon and push one end into the mixture filling the crater, let the other end stick out of the crater for a fuse.
4. Light the magnesium ribbon fuse with a match and stand back! (If the eruption did not set off, wait a few moments, then insert a second fuse and try again).
5. After the eruption, a second eruption can be simulated by pouring more of the bichromate-magnesium powder mixture into the crater while it is still hot (use a long paper or cardboard chute to fill crater).

What questions to ask:

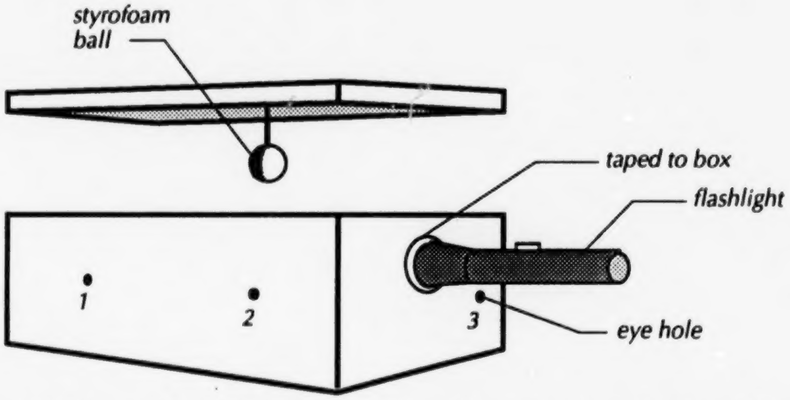
1. What is the function of the magnesium ribbon?
2. What was the cause of the eruption (as a chemical reaction)?
3. What causes an actual volcano to erupt?
4. What comes out of the crater of an actual volcano?
5. How can actual volcanic eruptions be predicted?

How to explain it:

Ammonium bichromate $(NH_4)_2Cr_2O_7$ is a very strong oxidant and unstable when heated. At the time that the magnesium ribbon flare touches the mixture of bichromate and magnesium powder, the bichromate decomposes into ammonia gas, chromium oxide, and oxygen. In the presence of the magnesium powder it also forms magnesium chromate. The sudden formation of the gases is the main cause for the upward spray and spewing out of the chemicals out of the crater. **A real volcano** erupts because of the pressure built up in the earth. The craters in the volcanoes are acting as valves through which this earth's pressure is released. When erupting, a volcano spews hot molten earth, called **magma** (underneath the earth's surface) or **lava** (above the earth's surface) out of the crater.

3.3.10. WHAT CAUSES THE PHASES OF THE MOON ?

What you need: 1. A large shoe box, carbon paper or other black paper.
2. A styrofoam ball (about 5 cm in diameter).
3. A small strong flashlight, masking tape , black thread.



How to do it:

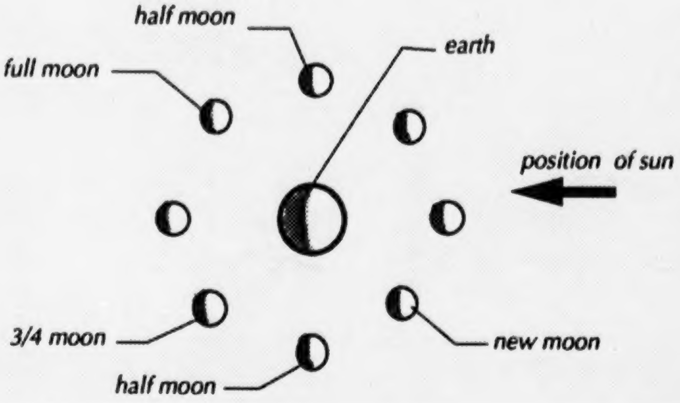
1. Cover the inside of the shoe box with black paper by gluing or placing small rolls of masking tape between the paper and the box.
2. Suspend the styrofoam ball from a black thread of about 2 cm long, and tape the thread against the center of the lid (see sketch).
3. Cut a hole the size of the flashlight at the end of the box and seal any space around it with masking tape .
4. Make five eye holes in the sides of the box: two on each long side and one at the end of the box obliquely under the flashlight.
5. Put the lid with the suspended ball on the box and seal the edges around it with masking tape.
6. Look through the eye holes and observe the ball (with the flashlight on) in the order numbered in the sketch.

What to ask:

1. What do you see when you look through the eye holes?
2. Turn the flashlight off; what do you see through the eye holes?
3. Looking through which of the holes gives you a similar picture as looking at the new moon?
4. What is it that causes the phases of the moon?

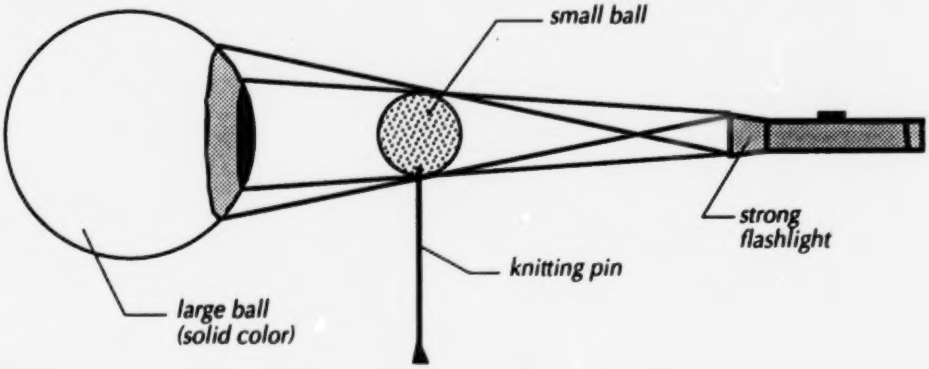
How to explain it:

Perhaps the best way to explain seeing the eight different phases of the moon is the illustration on the right. A quarter **new moon** would correspond with the sight by looking through hole 1, **half moon and three quarter moon** by looking through hole 2, **full moon** by looking through hole No.3, etc.



3.3.11. WHAT CAUSES AN ECLIPSE ?

What you need: 1. A strong flashlight, slide projector, or other light source.
2. A large (20 cm diameter) solid color sphere.
3. A small (5 cm diameter) rubber or styrofoam ball. 4. A knitting needle.

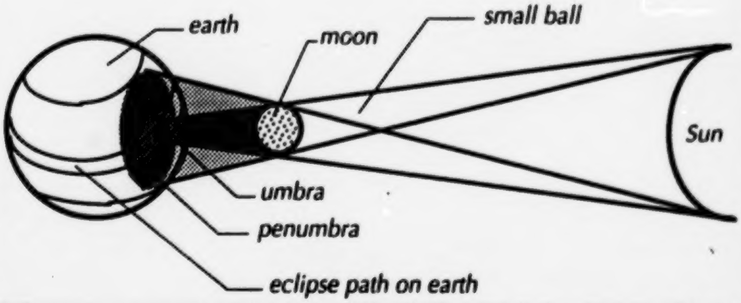


How to do it:

1. Stick the knitting needle into the small ball, so that you can hold it between the light source and the large ball without casting a shadow of your hand on the large ball.
2. Hold the smaller ball between the light source and the large sphere and adjust the distance from the sphere, such that the small ball casts a dark shadow in the center and a greyish shadow on the edges. (see sketch)

What to ask:

1. What does it mean if something is eclipsed?
2. For a solar eclipse to occur, how must the earth, sun, and moon be positioned in relation to each other?
3. Would all people on earth be able to see a solar eclipse when it occurs?
4. At what time (day or night) can a solar eclipse be observed?
5. How must the earth, sun, and moon be positioned in relation to each other, in order for a lunar eclipse to occur?
6. What are safe ways to observe a solar eclipse?



How to explain it:

The light source represents the sun, the large sphere the earth, and the small ball the moon. In order for a **solar eclipse** to occur, the moon must be positioned between the earth and the sun. For a **lunar eclipse** to occur, the earth must be between the sun and the moon. Only those people living in the eclipse path can see either a partial (those in **penumbra**) or a total eclipse (those living in the **umbra**). (see sketch on right)

INDEX

A

absorbed 25
ACCELERATED MOTION 71
acceleration 7
  constant 94
action 43
  and reaction 73, 75
ADHESION 18
ADHESIVE FORCES 28
air friction 50
AIR RESISTANCE 20
Ammonium Bichromate 107
amplitude 33
ANGULAR MOMENTUM 88 - 91
  The Tin Can Race 92
angular momentum
  conservation of 89 - 91
ANOTHER BALANCING ACT 64
APPLE AND THE KNIFE 70
ASTRONOMY 108, 109

B

BALANCING ACT 10
Balancing Act 20
BALANCING PINS 9
Balancing Point 14
Ball Bounce 86
BALLOON RACE 72
Bicycle Wheel 91
black box 35
BLOW YOUR OWN SAIL ? 76
Boyancy Force 105
BREAK THE STRING WHEREVER YOU WANT 68
BURNING CANDLE SEESAW 13

C

CAN PLANTS BREAK ROCKS ? 101
CAN STONES DISSOLVE ? 100
CAN WE GET THE CORK OUT? 43
CAN WE GET THE CORK OUT? (II) 44
Cardboard 14
CARDBOARD BOTTOM 30
carpentry 52
caves
  underground 99
center
  geometric 88
CENTER OF GRAVITY 9 - 23, 27, 48, 88
  Air Resistance
    Stand a Dollar Bill on Your Finger 20
  Shock Absorbers
    The Standing Matchbox 19
  Spinning Objects
    Kick A Straight Line 22
  The Plate Carousel 12
  Where is the Balancing Point? 14
Center of Gravity 12 - 14, 16, 17, 19, 22, 23, 64
CENTER OF GRAVITY SUDDEN STRESSES 36
center of gravity. 22
center of mass 10, 26
center of rotation 90
CENTER-SEEKING PAPER 18
centrifugal 78
CENTRIPETAL FORCE 78 - 82
CHAPTER 2
  SPACE SCIENCE 59
CHAPTER 1
  HOW DO FORCES AFFECT THINGS? 3
CHAPTER 3
  EARTH SCIENCE 97
Cohesive Forces 18
COLLIDING STEEL BALLS 85
COMPRESSION
  Water Pressure 45
conducted 25
CONFUSED TWIRLING PAPER 50
Conservation of Angular Momentum 90 - 91

CONSERVATION OF MOMENTUM 37, 77, 83 - 87
  Test Tube Cannon 87

Corkboard 14
CORRUGATED MATERIALS
  STRENGTH OF 40
couples
  clockwise 26
  counter-clockwise 26
CRACK A NUT 52
CRASHING SKATES 84
CRUSH THE CAN WITH A RUBBER BAND ? 49
CUP OF COFFEE DROP 93

D

density 105
  defined 106
DETERMINE THE ROCK'S VOLUME? 106
Dining Plate 12
DIRECTION OF FORCE 67
DIRECTIONAL OSCILLATIONS 51
directions
  opposite 76
Dollar Bill 20
DOLLAR BILL BRIDGE 40

E

EARTH SCIENCE
  Rocks & Density
    Determine the Rock's Volume 106
  Specific Gravity
    What is The Rock's S.G.? 105
  Volcanic Eruption 107
effort 53
Egg 23
ELASTICITY 37
elasticity
  of steel 37
energy level 90
Enthalpy 90
EROSION 103
EROSION & WEATHERING 99 - 102
erosion process 103

F

FALLING ELEVATOR 94
FALLING PENNIES 7
FALLING WASHERS 71
FIRST CLASS LEVERS 53
FLOATING BELT HANGER 24
FLYING WINE GLASSES 79
force
  shearing 46
FORCES
  Center of Gravity
    Adhesion 18
    HUman Body 17
    Shock Absorbers 19
    Spinning Objects 22, 23
    Where is the Balancing Point? 14
  Compression Water Pressure
    Water Hammer 45
  Free Fall
    Center of Gravity 48
  Friction
    The Invisible Glue 29
  GRAVITY 5
  Newton's Third Law
    Get The Cork Out 43
  Perpindicular Forces
    Crush The Can By Standing on it? 49
  Pressure vs Force
    Crack a Nut 52
  Rigidity
    Pierce a Potato with A Straw? 38
  Rotational Forces
    Torques 50
  Rotational Vibrations
    Directional Oscillations 51
  Stacking Force
    Sticky Knife 42
  Strechability
    Water Tight Ziplock Bag 47
  Strength of Corrugated Materials
    Dollar Bill Bridge 40
  Strength of Waeved Material
    Loose Knife Supports 39
  Stresses in Paper
    Hold The Burning Paper 41
  Water Pressure
    Cardboard Bottom 30
    Vortex in A Liquid 32
forces
  adhesive 18
  cohesive 18
FORK AND THE SPOON ACT 25

FREE FALL 48
  Center of Gravity
    Mysteriously Moving Ball 48
free fall
  continuous 95
frequency 34
FRICTION 28, 29, 44
  Get The Cork Out II , 44
Friction 29, 33, 63, 65
FRICTION & TORQUES 27
fulcrum 53
full moon 108
FUNNY MARBLES 83

G

geometric center 88
GET THE CHALK IN THE BOTTLE 67
GET THE EGG IN THE GLASS 66
GEYSER ACTION 104
GOLDEN MIDDLE 27
GRAVITATION 81, 82
GRAVITY 5, 6, 7, 8
gravity 93
GRAVITY MACHINE (I) 81
GRAVITY MACHINE (II) 82

H

half moon 108
Handkerchief 23
HANG A HAMMER ON A LOOSE RULER 11
hardness scale) 100
HIT THE BOTTLE ON THE BACK SWING ? 33
HIT THE FALLING CAN 8
HOW CAN WATER BREAK ROCKS ? 102
HOW CAN WE DETERMINE THE ROCK'S VOLUME? 106
HOW CAN WE GET THE CORK OUT ? (II) 44
HOW CAN WE GET THE CORK OUT? (I) 43
HOW DOES A GEYSER WORK ? 104
HOW HIGH WILL THE BALL BOUNCE ? 86
HOW LONG CAN YOU HOLD THE BURNING PAPER ? 41
HOW MANY SWINGS CAN YOU GET ? 34
HUMAN BODY 15, 17
HUMAN GYROSCOPE 91

I

illusion 5
imagination 44
IMMOVABLE PENNY 63
impact
  point of 19
INCLINED PLANE 56
INCREDIBLE STICK 36
INERTIA 61 - 63, 66 - 68
  Newton's First Law 66
influx of energy 36
Innertia 65
INVISIBLE GLUE 29
IS THE BALL REPELLED ? 37
IS THE HAMMER A LEVER ? 54
ISOSTATICS 103

K

KICK A STRAIGHT LINE 22
kindling point 25
Knives 39

L

labile
  system 11
LATENT FORCES 35
Lava 107
Lazy Susan 82
less dense
  areas 81
liquid pressure 31, 93
LOOSE KNIFE SUPPORTS 39
lunar eclipse 109

M

MAGIC COME-BACK CAN 35
MAGIC STRIP OF NEWSPAPER 28
Magma 107
Magnesium Powder 107
Magnesium Ribbon 107
MAKE STALACTITES & STALAGMITES 99
MANY SWINGS CAN YOU GET? 34
mass
  and velocity 83
  of an object 61

MATCH MISSILE 73
Matchbox 19
MEASURE THE CENTRIPETAL FORCE 80
MILK CARTON SPRINKLER 74
minerals 99
moment 13
MOMENT OF INERTIA 90, 92
Momentum 37, 86
momentum
  conservation of 77
  conserved 86
motion
  objects in 69, 70
MYSTERIOUSLY MOVING BALL 48

N

new moon 108
Newsprint Paper 22
NEWTON'S FIRST LAW 64, 65, 68 - 70
  Another Balancing Act 64
  Pull The Dollar Bill Out 65
NEWTON'S FIRST LAW 66
Newton's First Law)
  second part 79
NEWTON'S LAW 45
NEWTON'S SECOND LAW 7, 8, 71
NEWTON'S THIRD LAW 43, 72 - 76

O

Objects
  at rest 45
oscillations 51
OUTPOUR RACE 32

P

packed 42
PAPER CARD BOOMERANG 89
Parallelogram 18
PENDULUM 34
penumbra 109
PERPENDICULAR FORCES 49
PIERCE A POTATO WITH A STRAW ? 38
Pivot 13
pivot 53
Pivot Point 12, 16
pivot point 9, 11, 64
plane of rotation 88 - 91
PLATE CAROUSEL 12
Potato 38
PRECESSION 91
pressure 38
  build-up 104
  liquid 31
PRESSURE VS FORCE 52
PULL THE DOLLAR BILL OUT?! 65
PULL THE TABLECLOTH 62
PULLEYS 57
pulverization 101
PUSH A NEEDLE THROUGH A BALLOON ? 46
PUT THE COIN IN THE CUP 61

R

reaction
  opposite 43, 73
RECOIL 87
RECOILING SKATE 77
resistance 53
  AIR 6
RIGIDITY 38
ROCKS & DENSITY 106
ROLLING UPHILL ? 5
rotating
  objects 36
rotation
  speed of 80
ROTATIONAL FORCES 50
ROTATIONAL VIBRATIONS 51
Rubber Cement 28

S

salts
  dissolved 99
SECOND CLASS LEVERS 54
SHEARING
  Needle Through a Balloon 46
SHOCK ABSORBERS
  Center of Gravity 19
SIMPLE MACHINE 55
SIMPLE MACHINES 53, 54, 56, 57
SIMULATE A VOLCANO ERUPTION 107
solar eclipse 109
SPACE SCIENCE
  Angular Momentum

    Moment of Inertia 92
    Spinning Football 90
  Angular Momentum Precession
    Human Gyroscope 91
  Centripetal Force
    Gravitation 81, 82
  Conservation of Momentum 86
  Consevation of Momentum
    Recoil 87
  Inertia
    Newton's First Law 66
  Newton's First Law
    Another Balancing Act 64
    Pull the Dollar Bill Out 65
  Newton's Third Law
    Straw Rocket 75
  Weightlessness
    The Cup of Coffee Drop 93
    The Weightless Nail 95
SPECIFIC GRAVITY 105
SPINNING FOOTBALL 90
SPINNING OBJECTS 21 - 23
  Center of Gravity
    Kick A Straight Line 22
SPINNING PLANETS 88
SQUIRTING WATER HOLES 31
stable
  system 10
STACKING FORCES
  Sticky Knife 42
stalactites 99
stalagmites 99
STAND A DOLLAR BILL ON YOUR FINGER 20
STAND A RAW EGG ON ITS HEAD 23
STANDING MATCHBOX 19
STICKY KNIFE 42
STICKY PENNY 78
strain 68
STRAW ROCKET 75
STRENGTH OF CORRUGATED MATERIAL
  Dollar Bill Bridge 40
STRESSES IN PAPER 41
STRETCHABILITY 47
STUCK TO THE WALL? 17
support
  point of support 11
surface
  larger 52

T

Talcum Powder 28
tension
  in paper 41
  in rope 57
TEST TUBE CANNON 87
THIRD CLASS BICEPS 55
THIRD CLASS LEVERS 55
Third Law of Newton 77
TILT A HEAVY LOAD WITH ONE FINGER 53
TIN CAN RACE 92
Torque or Moment 13
TORQUES 13, 24 - 26, 50
  Center of Gravity
    Burning Candle Seesaw 13
transformed
  into heat 33

U

umbra 109
UNREACHABLE CUP 16

V

vibrations 51
VOLCANIC ACTION 104
VOLCANIC ERUPTION 107
vortex
  formation 32
VORTEX IN A LIQUID 32

W

water
  expanding 102
WATER HAMMER 45
WATER PRESSURE 30 - 32, 45, 47
  Squirting Water Holes 31
WATER-TIGHT ZIPLOCK BAG 47
WEAVED MATERIAL
  STRENGTH OF 39
weaving
  structure 39
weight 68
WEIGHTED PIPE 26

WEIGHTLESS NAIL 95
WEIGHTLESSNESS 93 - 95
WHAT BREAKS THE THREAD ? 69
WHAT CAUSES AN ECLIPSE ? 109
WHAT CAUSES THE PHASES OF THE MOON ? 108
WHAT IS THE ROCK'S S.G.? 105
WHERE IS THE BALANCING POINT? 14
WHICH ONE IS HEAVIER ? 56
WHICH ONE WILL BE MOVED ? 57
WHY DO ERODED MOUNTAINS KEEP RISING ? 103
WILL PAPER FALL LIKE A STONE ? 6
WOBBLING CIRCLES 21
WOMEN STRONGER THAN MEN ? 15

Y

YIP-YIP STICK 51

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